Appendix – Full papers

Service Networks Modelling: An SOA & BPM Standpoint

Olha Danylevych
(Institute of Architecture of Application Systems, University of Stuttgart, Germany
olha.danylevych@iaas.uni-stuttgart.de)

Dimka Karastoyanova
(Institute of Architecture of Application Systems, University of Stuttgart, Germany
dimka.karastoyanova@iaas.uni-stuttgart.de)

Frank Leymann
(Institute of Architecture of Application Systems, University of Stuttgart, Germany
frank.leymann@iaas.uni-stuttgart.de)

Abstract: Services are quintessential in the current economical landscape. Enterprises and businesses at large rely on the consumption and providing of services to ensure their operations and to realize their business offers. That is, nowadays businesses all over the world are interconnected with each other by complex service-centric webs called *service networks*. The ubiquity and pervasiveness of service networks call for models, methods, mechanisms and tools to understand them and harness their potential.

This paper investigates the modelling of the service networks with a focus on business relationships and exchanges of software services among the involved parties. The contribution of this work is threefold. Firstly, we provide an overview of what service networks modelling can offer in combination with Business Process Management (BPM) and Service Oriented Architecture (SOA) technologies. Secondly, we propose a formalism to model service networks that depicts them as aggregations of participants – e.g. enterprises or individuals – that offer, request, consume and provide services to each other. With the goal of providing a foundation for the alignment between service network- and business process models, we finally map the constructs of our service networks modelling formalism to the ones of the Business Process Modelling Notation (BPMN).

Key Words: service networks, service oriented architecture, software services, business process management, business processes, BPMN
Category: D.2.9, H.1, H.3.5

1 Introduction

We live in "services times". Services are paramount in the global economy. In western societies like USA and Germany more than 60% of the work force is devoted to the delivery of services [Maglio 06]. The meaning of the term "service" itself is changing to keep up with the times. Originally, the economical meaning of service was (1) an intangible type of good or (2) a value-increasing addition to a good [Maglio 09]. Nowadays, however, it has evolved to “the process of doing something for another party, without reference to goods as the primary focus of the exchange activity” [Maglio 09].

Everyone taps into services every day by using Google, Facebook, Twitter, online banking facilities, webmail applications of choice, etc. But services are not only an Internet-related phenomenon. For example, education at large can be seen as a service system, as well as call centers, IT support [Maglio 06], and telecommunication [Buford 01].From the business perspective, the importance of services for modern enterprises has led to the rise of the Service Oriented Computing (SOC) paradigm [Papazoglou 07a, Papazoglou 08] and its technological embodiment Service Oriented Architecture (SOA) [Papazoglou 07b].

Enterprises rely on services provided to them by other parties for the realization of their own service offers. The interconnections in terms of services offered and required by enterprises shape complex webs called *service networks*. Furthermore, service networks are not phenomena occurring only among distinct businesses. In fact, service networks exist as well inside enterprises because of the interplay among business units, divisions, departments, etc. In the turmoil of nowadays globalized economy we need models, methods, mechanisms and tools to understand and deal with service networks.

Service networks are at the crossroad of many different and converging disciplines, each approaching the topic from a different point of view and focusing on different aspects [Maglio 09]. In the state of the art service networks come under many names such as service system [Maglio 06, Caswell 08], service ecosystems [Barros 06], and service value networks [Blau 09]. Approaches to service networks with an economy focus are mainly concerned with the creation of value [Gordijn 01, Biem 08, Allee 08, Caswell 08]. On the contrary, the business communities investigate the structure of organizations in service networks [Camarinha-Matos 06, Steen 02] and related business models [And. 05, Osterwalder 04]. The SOA and Business Process Management (BPM) communities focus on the technology to realize and operate service networks and automate the business processes that take place inside them.

Our contribution comes under the SOA and BPM banner. We envision service networks modelling as the means to gain better alignment between the business and IT perspectives in enterprises. The enhanced alignment is achieved by (1) providing an overview of inter- and intra-enterprise business relationships in terms of service offerings and providings, (2) supporting decision making on service networks in terms of business relationships between participants, and (3) facilitating the propagation of changes from service networks to the underpinning software service infrastructures and vice versa.

This work focuses on service networks built around *software services*, i.e. services that are provided over a software infrastructure and that do not involve the exchange of physical goods between parties. We propose a formalism to model service networks as aggregations of participants (organizations, individuals, etc.) that provide services to and consume services from each other. Moreover, we lay the foundations for aligning service networks with the technologies that undergird them. This is accomplished by establishing correlations between the service networks modelled with our formalism and the business processes modelled with the Business Process Modelling Notation (BPMN) version 1.2, the de-facto standard for modelling the operational aspects of business processes at BPM level.

The paper is structured as follows. Section 2 introduces the running example that is used throughout the paper to exemplify the proposed concepts. Section 3 outlines the role of service networks modelling with respect to BPM and SOA, and shapes the overarching scope of our research. Section 4 presents the formalism to model service networks. In Section 5 we investigate the alignment of service network- and business process models. The related work is treated in Section 6. Finally, Section 7 concludes the paper by presenting the closing remarks.

2 The Running Example: The SomeTunes Media Store

The running example of this paper is a fictional service network centred on the online Media Store "SomeTunes" and encompassing SomeTunes' customers and the service providers it relies on.

The SomeTunes D, subordinated to Mango Inc, runs an online media store offering services that sell music, movies and applications for mobile devices (smartphones, tablets, handheld music players) running the Anthropoid mobile operative system. Each of the service offerings of SomeTunes can be accessed separately by its customers. For the sake of brevity, in this scenario we restrict ourselves to four customers: Alice, Bob, Carl and John. The customers are individuals, and consume different combinations of SomeTunes' service offerings. Alice buys Athropoid applications, Bob buys some music, Carl buys movies and their soundtracks, and John buys movies and unrelated music.

SomeTunes relies on external payment services for handling customers' online payments. Customers of SomeTunes can currently choose between the payment services offered by the PayDude and OverlordCard companies. From the point of view of SomeTunes, the particular payment service provider adopted in a given transaction with a customer is of marginal importance because both of them implement a common interface and apply equivalent commission fees.

SomeTunes does not develop the Anthropoid applications it sells. Instead, it offers a platform for enabling application publishers to sell their products. The platform has just been launched, and the only publisher currently using it is

Snowstorm Publisher. Customers who buy Snowstorm Publisher's applications on SomeTunes are required to activate them by contacting a software service provided by Snowstorm Publisher.

3 The Scope of Service Networks

This section discusses the scope of our research on service networks and their application to the practice of BPM and SOA. Section 3.1 covers the modelling of service networks. The analysis of service network models is treated in Section 3.2. Section 3.3 describes how service network models can be used to depict either actual or hypothetical service networks. Finally, Section 3.4 discusses the change management of service network models.

3.1 Modelling Service Networks

Service networks modelling aims at providing an overview of the interplay among service consumers and providers while abstracting from the technical details of business process- and service composition modelling. Service networks modelling is applicable to both inter- and intra-organization scenarios, which respectively describe the interactions among organizations and, inside a business, among divisions, departments, units, etc.

The description of a service network is a combination of several elements, namely (1) ***participants***, (2) the ***service requests*** and ***service offerings*** that populate the network, and (3) the *relationships between participants*, e.g. ***business relationships*** or ***service providings***. The consumption of services is implied by the service providings, i.e. providing and consuming a service are the same relation from different points of view.

Our approach to service networks modelling adopts an *instance* point of view. That is, our goal is to enable the modelling of *concrete* service networks, i.e. real service networks that are made of actual participants (e.g. the SomeTunes Division in the running example) in contrast with the roles they play (e.g. Music Reseller or Application Store). We wish to underline that role and instance perspectives on service networks modelling must ultimately reconcile. For example, practitioners should be able to relate participants of instance service networks to the more abstract roles they play. Bringing together instance and role points of view of service networks modelling is in the overarching scope of our research. However, in this paper we restrict ourselves to the modelling of instance service networks because we believe that the instance point of view is the one on the basis of which business decisions are taken. For example, when a business has to decide which providers to rely on for the provisioning of some services, the roles alone do not convey enough information about the available options, i.e. the actual providers. Instead, business analysts need to visualize the concrete contracts, service offerings, etc., that are input to the business decisions and that are available only from the instance perspective.

The participants in a service network are of two types: individuals, i.e. natural persons (humans), and business entities, e.g. organizations and consortia. Participants can establish relationships among each other, which can be grouped into business- and structural relationships. Business relationships describe for example strategic alliances between organizations, and have implications on how service networks operate and change over time.

Structural relationships model how the business entities and individuals relate to other participants in terms of organizational structures. One business entity can be subordinated to another, e.g. the subordination of the SomeTunes Division to Mango Inc. Another structural relationship is the affiliation of an individual to a business entity, e.g. Steve Works (Mango Inc.'s CEO) is affiliated to Mango Inc. Structural relationships are relevant to the change management of service network models, because they may impose constraints to which changes can actually be applied.

Participants in a service network can be both consumers and providers at the same time. Consumers are participants that need services, and they issue service requests to advertise their needs. Service requests state the characteristics of the required services, e.g. in terms of functionalities and Quality of Service, and the conditions under which they should be provided, e.g. acceptable price ranges. Providers make their services available to other participants through service offerings. A service offering is the description of a service plus information on the conditions under which the service is made available, for example pricing schemes and contractual obligations.

The consumption of services takes place over service providings. A service providing is a particular type of relationship that occur between a provider and a consumer and that consists of the actual delivering of one or more provider's services to the consumer. Service providings are regulated by contracts that specify the terms and obligations that regulate the exchange.

3.2 Analysis of Service Networks

Service networks modelling aims at facilitating the management of service offerings, requests and providings between and inside organizations. To reach this goal we need analysis methods that support the decision making concerning change and optimization of service networks.

The state of the art of service network analysis is still limited and currently centered on the economical perspective (see Section 6). For example, in our previous work we have investigated the optimization of value in service networks [Bitsaki 08a]. Other analysis methods focus on profitability and sensitivity [Gordijn 01] and value flows [Allee 08]. Future research will need to develop analysis methods that bridge the economical, operational and technological aspects of service networks. For instance, we envision methods for analyzing long-term collaborations among partners to discover and prioritize which underlying business processes and service compositions should be optimized. Another interesting research direction is the analysis of service network for discovering patterns of interactions among participants. Through the mapping to the underlying business process models (see Section 5), this would results in the discovery of reference models and reusable fragments of business processes and service compositions that will simplify the creation and management of value-adding constellations.

Both local (one or more participants) and the global (the whole service network) perspectives should be supported by the next generation of analysis methods for service networks. In general, the perspectives employed by the analyses will depend on the scenarios depicted by the analyzed service networks. In service networks that model inter-organizational business relationships, the analysis will mainly aim at optimizing the situation of single participants or participant groups, i.e. local optimization. On the contrary, the analysis of intra-organizational service networks could be performed from a global perspective with the goal of optimizing the overall performance of the enterprise.

3.3 "As Is" and "To Be" Service Networks

Service network models either capture the state of existing interactions among participants – service networks "as is" – or depict planned service networks – service networks "to be". Service network models "as is" will be created bottom-up by extracting information from business process models, logs, service compositions, SLA agreements and contracts among parties. The analysis of "as is" service network models will support decision making for adapting and optimizing the behaviour of participants, e.g. in terms of services provided or consumed, explore possible optimizations, and detect underperforming participants on the basis of monitoring.

Service network models "to be" will be created either top-down or by modifying "as is" models. The analysis of "to be" service network models will employ simulation and predictions to outline "what if" scenarios. The service network models will then be used as starting points for implementing the business processes and service compositions that will operationalize the business relationships.

3.4 Change Management

Service network models change for a number of reasons. In "as is" service network models, changes are required to keep the alignment between the model and the reality of the service network.

Changes to service network models result from the application of change operators like the removal of a service offering, the addition a participant, or the modification of existing service requests. The change operators should be correlated with change operators for business process- and service composition models to streamline the implementation of the changes through the technology stack underpinning actual service networks.

In this paper we lay a foundation for the correlation of changes at the different levels by analyzing the correspondences between constructs of service network models and the ones of business process models in Section 5.2.

4 A Formalism for Modelling Service Networks

This section describes the formalism to model service networks based on hypergraphs, i.e. generalizations of graphs in which edges – in this case called hyperedges – connect two or more nodes. The constructs are exemplified on the basis of the "SomeTunes" running example proposed in Section 2. We have depicted the running example in Figure 1 using a simple graphical notation instead of showing hypergraphs for the sake of understandability.

4.1 Service Networks

A service network model is a directed hypergraph formally defined as:

$$\mathcal{G}_{sn} = (\mathcal{V}, \mathcal{E})$$

In a service network there are three types of nodes: participants (denoted by $\mathcal{P}$), service requests ($\mathcal{R}$) and service offerings ($\mathcal{O}$). That is:

$$\mathcal{V} = \mathcal{P} \cup \mathcal{R} \cup \mathcal{O}$$

The hyperedges of a service network represent either business relationships ($\mathcal{L}$), ownership of service offerings ($\mathcal{E}_o$), ownership of service requests ($\mathcal{E}_r$), service providings ($\mathcal{E}_p$), service providing dependencies ($\mathcal{D}_{prov}$) or participant internal dependencies ($\mathcal{D}_i$).

$$\mathcal{E} = \mathcal{L} \cup \mathcal{E}_o \cup \mathcal{E}_r \cup \mathcal{E}_p \ \cup \mathcal{D}_{prov} \cup \mathcal{D}_i$$

In the reminder of the section we examine in detail the different types of nodes and edges. In particular, Section 4.2 treats participants and business relations. Section 4.3 covers service offerings and their ownership. Service requests and their ownerships are examined in Section 4.4. Section 4.5 treats service providings and service providing dependencies. Finally, Section 4.6 discusses participant internal dependencies.

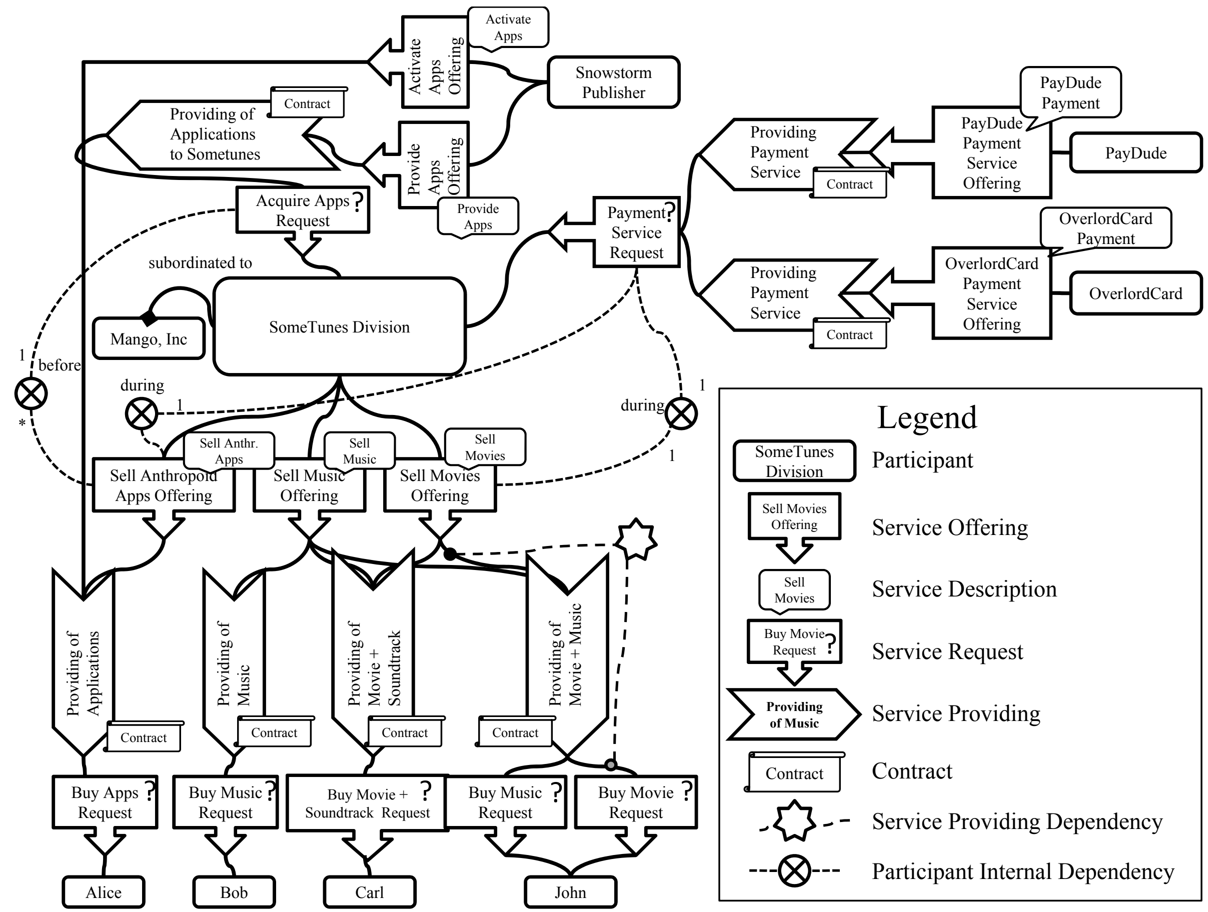


Figure 1: A graphical representation of the service network of the running example

4.2 Participants and Relations Among Them

The ***participants*** of a service network are either business entities (denoted by $\mathcal{B}$) or individuals (denoted by $\mathcal{I}$). That is:

$$\mathcal{P} = \mathcal{I} \cup \mathcal{B}$$

We wish to reiterate that participants in our service network models are actual, concrete participants, in contrast with mere roles. In our scenario, we have four business entities, namely Mango Inc, the SomeTunes Division, PayDude, and OverlordCard, Snowstorm Publisher, and four individuals, i.e. the consumers Alice, Bob, Carl and John.

We are aware of the fact that modelling each actual participant in a service network will lead in some cases to an explosion of the number of elements in the models, in particular when modelling customers in Business to Consumer (B2C) scenarios. However, this is not a disadvantage of our approach itself, as it is an issue that has been encountered for example in databases. And there are valuable lessons to be learned from the database community. In future research we will explore the possibility to support ***views*** in the modelling notation and the connected tooling. Views will enable the collapsing of multiple analogous participants (as well as service offerings, requests, etc.) in groups of manageable size.

Participants in a service network can be connected by *business relationships* that represent, for example, strategic alliances or partnerships. The role of contracts in service network modelling is to set constraints to how the networks (and the underpinning business processes) evolve. For example, the obligations specified in a contract signed by two participants might prevent one to offer in the future certain types of services due to a non-compete clause. In this work we refrain from providing a formalization of generic business relations, and instead focus on the structural ones (and the service providings later on). ***Structural relationships*** pertain to how participants are organized hierarchically. Individuals can be affiliated to business entities, e.g. organizations. Affiliations in a service network connect the individuals in the service network to the business entities they are affiliated to, and can be formalized as follows:

$$\mathcal{A} \subseteq \mathcal{I} \times \mathcal{B}$$

In our running example we have no affiliations. However, it is easy to envision scenarios in virtual networks and/or human-provided services in which the affiliation of individuals is an element to take into consideration in the modelling and management of service networks.

Business entities can be subordinated to one or more other business entities, e.g. divisions are subordinated to enterprises. Formally:

$$\mathcal{F} \subset \mathcal{B} \times \mathcal{B} \,:\, (b_1, b_2) \in \mathcal{F} \Rightarrow b_1 \neq b_2$$

As a convention, the first business unit in the relationship is subordinated to the second (b_1 subordinated to b_2 in the above formalization). In the running example the subordination relationship is exemplified by the fact that the SomeTunes Division is subordinated to Mango Inc. We do not impose restrictions to the subordination, for example we do not require the subordination of business entities to other to form a tree. This is because we wish to support the modelling of virtual organizations, i.e. the business entity resulting from the sharing of resources by independent organizations aiming at achieving some shared goals [Camarinha-Matos 04, Zirpins 09], alongside the more usual hierarchical, inter-enterprise organizational structures.

It should be noted that, in a sense, also service providings are relationships connecting the participants in service networks. However, they to not exactly connect the participants, but instead the service offerings and requests those participants provide. We treat service providings separately in Section 4.5.

4.3 Service Offerings

The services in a service network (i.e. the functionalities that are exposed by the participants) are represented as ***service offerings***. In the running example there are the "Sell Anthropoid Apps Offering", "Sell Music Offering" and "Sell Movies Offering" of SomeTunes Division, the two distinct "Payment Service Offerings" of PayDude and OverlordCard, and the "Activate Apps Offering" and "Provide Apps Offering" of Snowstorm Publisher.

Service offerings are aggregations of information that describe functional and non-functional properties of the services that are offered. The functional properties specify *what* the service does, e.g. in terms of the International Standard Industrial Classification of All Economic Activities (ISIC) revision 4 [1]. The non-functional properties specify how the functionalities are carried out, e.g. in terms of Quality of Service. The "Sell Music Offering" may contain, for example, the following data:

- Functional Properties: (1) ISIC rev 4 codes: 4762 (Retail sale of music and video recordings in specialized stores) & 4791 (Retail sale via mail order houses or via Internet); (2) Supported File Formats and Bitrates: MP3 (512 kbit/s), FLAC, OGG Vorbis (512 kbit/s); (3) Digital Rights Management (DRM): none
- Non-Functional Properties: (1) Download rate: from 50 KB/sec to 1 MB/sec; (2) Download availability: 99%

The exhaustive enumeration of the types of additional information in the service offerings is outside the scope of this work. Examples of such information

[1] ISIC Website: `http://unstats.un.org/unsd/cr/registry/isic-4.asp`

can be found in the pricing and legal profiles of the Unified Service Description Language (USDL)[2]. The interested reader will find in [Andrikopoulos 08] a generic way of representing functional and non-functional properties of offerings.

Each service offering in a service network belongs exactly to one participant. Notice that in a service network model there might be distinct service offerings that are equivalent because they contain exactly the same data. Equivalent service offerings may each belong to different participants, or multiple may belong to one participant that wishes the duplication for some reason. The ownership relation between participants and their service offerings is represented by the edges $\mathcal{E}_o$ that are formalized as:

$$\mathcal{E}_o \subseteq \mathcal{P} \times \mathcal{O} \;:\; \forall o \in \mathcal{O},\ \exists p \in \mathcal{P} :\ \exists (p, o) \in \mathcal{E}_o \land \\ \nexists p_1, p_2 \in \mathcal{P},\ o \in \mathcal{O} :\ p_1 \neq p_2 \ \land\ (p_1, o) \in \mathcal{E}_o \land (p_2, o) \in \mathcal{E}_o$$

It is possible for participants not to have any service offerings (e.g. the customers in the running example).

4.4 Service Requests

A ***service request*** is a specification of the requirements that a participant sets on the services it needs, e.g. acceptable QoS or pricing. The structure of service requests is equivalent to service offerings' (i.e. functional, non-functional and additional information). However, while service offerings specify a description of an existing service, service requests specify minimal requirements that services must satisfy. For example, Bob's "Buy Music Request" might specify that he wants to buy music (e.g. in terms of the ISIC classification), the bit rate and file format desired, but do not set any requirements on the DRM systems.

The relation between the participants and their service requests are represented by the edges $\mathcal{E}_r$. Formally:

$$\mathcal{E}_r \subseteq \mathcal{P} \times \mathcal{R} \;:\; \forall r \in \mathcal{R} \;:\; \exists p \in \mathcal{P},\ \exists (p, r) \in \mathcal{E}_r \land \\ \nexists p_1, p_2 \in \mathcal{P},\ r \in \mathcal{R} :\ p_1 \neq p_2 \land (p_1, r) \in \mathcal{E}_r \land (p_2, r) \in \mathcal{E}_r$$

Likewise service offerings, each service request belongs to exactly one participant. Participants may however have equivalent service requests. It is not mandatory for participants in a service network to have service requests (in the running example this is the case of PayDude, OverlordCard and Snowstorm Publisher). As a matter of fact in our modelling notation for service networks it is possible for some participant to have neither service offerings nor service requests, such as Mango Inc in the running example. This is a deliberate design

[2] The USDL specifications are available at: `http://www.internet-of-services.com/index.php?id=54`

decision to account for situations such as when a participant has discontinued its services – for example a company that gets bought out by another one – but still retains business relations with other participants.

4.5 Service Providings and Service Providing Dependencies

A ***service providing*** is a relationship that connects one or more service requests with one or more service offerings that satisfy them and the contract (e.g. the license) that regulates the provisioning. The set of service providings in a service network is denoted by $\mathcal{E}_p$, formally specified as:

$$\mathcal{E}_p \subseteq \wp(\mathcal{R}) \times \wp(\mathcal{O}) \times \mathcal{C}$$

We recall that $\mathcal{R}$, $\mathcal{O}$ and $\mathcal{C}$ denote the sets of the service requests, service offerings and contracts modelled in the service network, respectively.

We have a flexible approach to service providings. We allow multiple service offers and requests from multiple providers and consumers to be combined in one service providing. One service offering might satisfy multiple service requests in the same service providing. The opposite case is also applicable, i.e. a service request is satisfied by a combination of service offers. Moreover, both service requests and service offerings may be involved in multiple service providings. On one hand, this enables the modelling of situations in which a service consumer relies on multiple providers to satisfy a service request. In the running example this is the case of the "Payment Service Request" of SomeTunes Division, which is satisfied by two distinct service providings. On the other hand, we can model situations in which the same service offering is involved in multiple providings (i.e. it serves multiple customers), such as the "Sell Music Offering" of SomeTumes.

Service providings are associated with contracts that specify the terms under which the consumption of services takes place. In our running example, the "Sell Music Providing" may be associated with an End User License Agreement (EULA) that, among other obligations, forbids the redistribution of the songs, fixes the terms for the termination of the licenses, and establishes the conditions for the reuse of consumers' personal data. It is outside the scope of this work to model the structure of contracts. The interested reader will find examples of methods to formalize contracts in [Daskalopulu 99, Telang 09]. Additionally, it falls outside the scope of this paper to specify how service providings come into existence, e.g. in terms of the negotiation processes that leads to them (see for example [Dang 06, Maglio 09]), how the discovery is performed (e.g. [Meshkova 08]), or how the matching between service offerings and requests is carried out (see for example [Kritikos 09]).

The relations between service offerings and service requests within one service providing are represented by ***service providing dependencies***. Service providing dependencies mark the fact that in a service providing some of the service offerings may realize only some of the service requests. Modelling dependencies in complex providings through service providing dependencies aims at facilitating the change management of the service providings (e.g. when a providing is revised and consequently split in two distinct ones), and the mapping of service networks to the underpinning BPM layer (see Section 5). The service providing dependencies in a service network are formalized as follows:

$$\mathcal{D}_{prov} \subseteq \mathcal{O} \times \mathcal{R} \; : \; \forall (o, r) \in \mathcal{D}_{prov} \;\; \exists (\tilde{R}, \tilde{O}, c) \in \mathcal{E}_p : o \in \tilde{O} \wedge r \in \tilde{R}$$

Consider "Providing of Movie + Music" between SomeTunes and John. The service providing aggregates two distinct offerings of SomeTunes, i.e. "Sell Music Offering" and "Sell Movie Offering", and two requests of John, namely "Buy Music Request" and "Buy Movie Request". For readability, we have depicted only the service providing dependency between "Sell Movie Offering" and "Buy Movie Request". In general, service providing dependencies can connect (pairwise) any number of offerings and requests inside the one service providing.

4.6 Participant Internal Dependencies

Participant internal dependencies are another type of dependencies in service network models beside service providing dependencies. A participant internal dependency relates one service offering and one service request belonging to the same participant. Its semantics is that the ability to provide the service offering by the participant depends on the satisfaction of the correlated service request. For example, the offering "Sell Anthropoid Apps Offering" of SomeTunes has two participant internal dependencies to "Payment Service Request" and "Acquire Anthropoid Apps Request".

On top of the dependencies between service offerings and service requests, participant internal dependencies specify two additional pieces of information: ***multiplicity*** and ***timing***. The multiplicity denotes the ratio between the satisfaction of service requests and units of related service offerings that can be provided. In our example, each instance of the "Sell Anthropoid Apps Offering" requires the satisfaction of one "Payment Service Request" (every time something is sold there must be an interaction with the payment service). Multiplicities can also be specified as intervals: the satisfaction of the "Acquire Apps Request" one or more times (multiplicity "1..*") allows any number of occurrences of the "Sell Anthropoid Apps Offering" (i.e. "*" in terms of multiplicity) because once an application has been uploaded to the SomeTunes platform, SomeTunes Division can resell it any number of times.

The timing of a participant internal dependency specifies the temporal relation between the satisfaction of the service request and the ability to provide the

Timing	Definition
equals	offering / request
meets	offering / request
during	offering / request
finishes	offering / request
before	offering / request
overlaps	offering / request
starts	offering / request

Table 1: The definitions of the possible values of timing in participant internal dependencies

service offering. The timing is specified using Allen's interval algebra [Allen 83], which defines a set of relations that specify all the possible ways two time intervals can relate to each other, e.g. in terms of equality or overlap. The possible values for the timing of the participant internal dependencies are shown in Table 1.

The set $\mathcal{D}_i$ contains the participant internal dependencies in a service network model, and it is formally defined as:

$$\mathcal{D}_i \subseteq \mathcal{P} \times \mathcal{O} \times \mathcal{M} \times \mathcal{R} \times \mathcal{M} \times \mathcal{T} \;:\; \forall (p, o, m_o, r, m_r, t) \in \mathcal{D}_i \exists (p, o) \in \mathcal{E}_o \wedge \exists (p, r) \in \mathcal{E}_r$$

$\mathcal{M}$ is the set of the possible multiplicities, and $\mathcal{T}$ are the possible timings (i.e. the entries of Table 1). Given the participant internal dependency (p, o, m_o, r, m_r, t), p denotes the participant, o is the offering of p, m_o is the multiplicity of o, r is the request of p, m_r is the multiplicity of r, and t is the timing.

5 Aligning Service Networks and the Business Process Management Stack

In order to make a service network happen, its participants have to field and employ a stack of technologies that are ubiquitous in the current practice of BPM and SOA like business process- and service composition models, service-oriented middleware, and software services. Service network models provide an overview of the relationships among participants while abstracting from the details of how the interactions among them take place, i.e. the operational details. Conversely, each business process realizes a part of a service network by specifying the operational details of the interactions among of some of the network's participants.

In general, a single business process model does not convey the entirety of the information available in a service network model because the business process (1) depicts operational information about only a part of the service network and (2) usually does not contain information on business relationships and contracts that occur between the participants. In other words, service network- and business process models have distinct – but related – purposes and perspectives, and therefore complete each other by tackling different aspects of the interconnections among businesses.

The interplay of service networks and business processes is such that it should be possible to create skeletons (i.e. incomplete models) of one from the other. We call *top-down* modelling the creation of business process skeletons from service networks. Conversely, *bottom-up* modelling is the extraction of service network skeletons from sets of business process models employed by one or more participants. The alignment of service network models and the corresponding business process models is essential. On one hand, the modifications to service network models must propagate to the related business process models. On the other hand, service network models should be updated according to the evolution of the underpinning business processes, which in turn depend on the underlying service compositions and service infrastructures, see for example [van den Heuvel 08].

To the end of aligning service network- and business process models, this section (1) shows how service networks relate to the underpinning stack of BPM and SOA technologies that realize them (Section 5.1), and (2) investigates the correspondences between the constructs of service network- and business process models specified using BPMN (Section 5.2).

5.1 The Technology Stack for Enacting Service Networks

The implementation of service network models in terms of real-world software services is based on the layering of BPM and SOA technologies shown in Figure 2. The Services layer comprises the set of software services that are available in the service network. The software services may be realized using SOA standards like SOAP, WSDL, and other WS-* specifications. Overviews of the technologies involved in the realization of these services are provided, for example, in [Weerawarana (05), Papazoglou(07)].

The Service Compositions layer deals with combining existing software services into composed, value-added ones. For reasons of space, we can provide only an overview of the service composition field. We reference the interested reader to more comprehensive surveys such as [Dustdar 05, Wetzstein 08].

In the state-of-the-art of SOA there are two main and most popular approaches to service composition: service orchestration and service choreography [Peltz 03, Busi 05, Barros 05]. Orchestration and choreography are two flips of the same coin: orchestration specifies a service composition from the local point

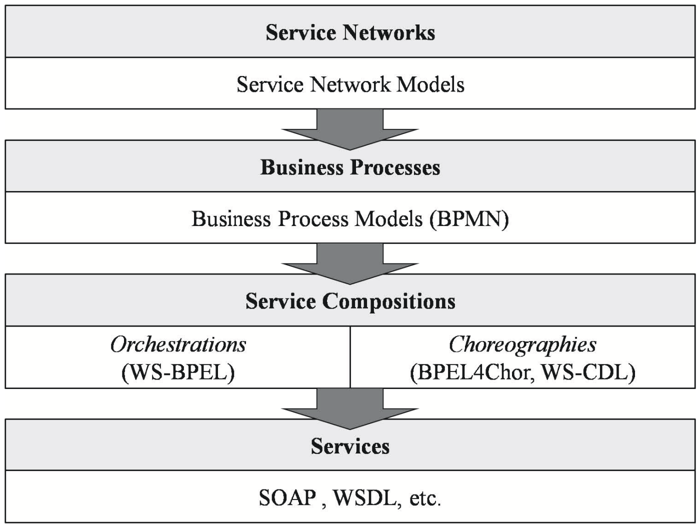


Figure 2: The technology stack for enacting service networks

of view of one single software service (the one that composes the others), while choreography assumes a global perspective on the service composition. On one hand, service orchestration is the service composition approach in which a new software service is created by invoking the composed software services and combining their outputs in some meaningful way. The internal logic of the new software service is specified using process flow languages, most notably the Web Service Business Process Execution Language (WS-BPEL)[3].

Service choreography specifies the ordering/sequencing of message-based conversations that are carried out by the composed software services. As opposed to service orchestration, each of the composed services is defined in terms of its perceived messaging behavior (called role), and its actual internal logic is not defined. Service choreographies are currently specified using languages and notations like BPEL4Chor [Decker 08] and Web Services Choreography Description Language (WS-CDL)[4].

The Business Process Models layer builds on the technologies and approaches specifies at the underpinning layers and deals with modelling abstract business processes. Abstract business process models are not executable, implementation-agnostic models of how the participants carry out the complex functionalities they provide. For example, abstract business process models define the ordering of the activities and interactions that are undertaken by the participants in order to execute the business processes. The aim of abstract process models is mainly

[3] The WS-BPEL specification is available at: `http://docs.oasis-open.org/wsbpel/2.0/wsbpel-v2.0.html`

[4] The WS-CDL v1.0 specification is available at: `http://www.w3.org/TR/ws-cdl-10/`

Service Network Constructs	**BPMN Constructs**
Participants	Pools
Service Offerings & Service Offering Ownerships	Lanes and workflows
Service Requests & Service Request Ownerships	Lanes and workflows
Service Providings	*implicitly modeled in the interactions among workflows of providers and consumers*
Service Providing Dependencies	*implicitly modeled in the interactions among workflows of providers and consumers*
Contracts	*no corresponding construct*
Business Relationships (e.g. Affiliation and Subordination)	*no corresponding construct*
Participant Internal Dependencies	*implicitly modeled in the way related offerings and requests are grouped in workflows and lanes*

Table 2: Correspondences between Service Network and BPMN constructs

to document and communicate how functionalities are going to be provided from a high level of abstraction. In order to be executed, abstract business processes are refined as service compositions, and deployed on the service infrastructure at the Services layer. The Business Process Models layer employs notations like the Business Process Modeling Notation (BPMN)[5] and Abstract BPEL, which is a subset of WS-BPEL that is also used at the Service Composition layer.

Finally, the Service Network layer sits on top of the Business Process Models layer, providing the means of analyzing, simulating and optimizing service networks.

5.2 Aligning Service Network and Business Process Models

Unlike business process models, service network ones abstract from the operational details of the processes (e.g. workflows) and focus on the business relationships occurring among the participants, the participants' offerings and requests of services, and the service providings and the relative contracts. The difference in focus and complementarity of service network- and business process models implies in the need of aligning them as one or the other changes in order to preserve the consistency.

[5] The BPMN v1.2 specification is available at: `http://www.omg.org/spec/BPMN/1.2`.

As a first step towards achieving this alignment, in this section we outline the correspondences between the constructs in service network- and business process models. We assume BPMN version 1.2 as the modeling notation for abstract business process models. It is outside the scope of this paper to provide formal means of transforming from service network- to business process models and vice versa. The interested reader will find an initial investigation of how service network models are refined to abstract business processes in our previous work [Bitsaki 08b].

The relations between service network- and abstract business process models are exemplified using the subset of the running example highlighted in Figure 3 and the corresponding BPMN business process that models shown in Figure 4. Table 2 summarizes our findings, which are detailed in the remainder of the section.

5.2.1 Service Network Constructs Explicitly Mapped to BPMN

Each service network participant is mapped to a BPMN pool. For each service offering and service request we create a lane in the participant's pool. In BPMN, a pool can contain multiple distinct workflows, each one included in a lane. In a sense, BPMN lanes are a way to define for the same participant multiple processes. The lanes of a pool can be related through control flows or other types of associations (e.g. events).

Service offerings and requests are mapped to lanes. Since lanes in BPMN are contained in pools, there is no need to explicitly represent service offering- and request ownerships. The workflow in each lane specifies the logic for realizing one or more service offerings and requests of one participant. If a service offering of a participant is related to some service requests by the means of participant internal dependencies, the relative operational logic of that participant that deals with the connected service offering and requests can be expressed by a single workflow. In other words, participant internal dependencies do not have a directly corresponding construct in BPMN, but are instead used to "cluster" the service offering and requests they relate in lanes. Consider for example the SomeTunes Division in Figure 4. The "Sell Anthropoids Apps Offering" has a participant internal dependency on the "Payment Service Request". Because of the clustering of the operational logic realizing service requests and offerings related by participant internal dependencies, there is no dedicated lane for 'Payment Service Request" and instead its logic is incorporated in the "Sell Anthropoids Apps Offering" lane.

As anticipated in the beginning of the section, service network models provide no information concerning the details of the logic that realizes service requests and offerings of participants. We have refined the workflows of Alice and SomeTunes in Figure 4 for explanatory purposes. What can be generally generated

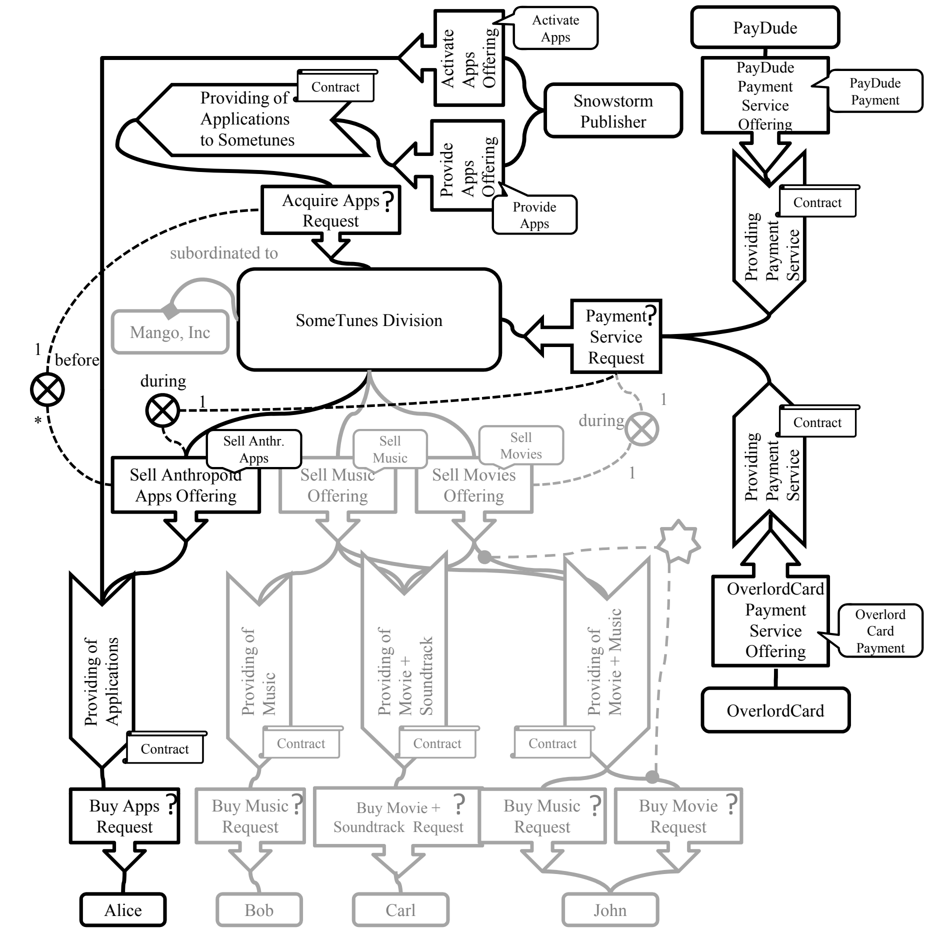


Figure 3: The subset of the running example that we use to explain the mapping between constructs of service network- and abstract business process models

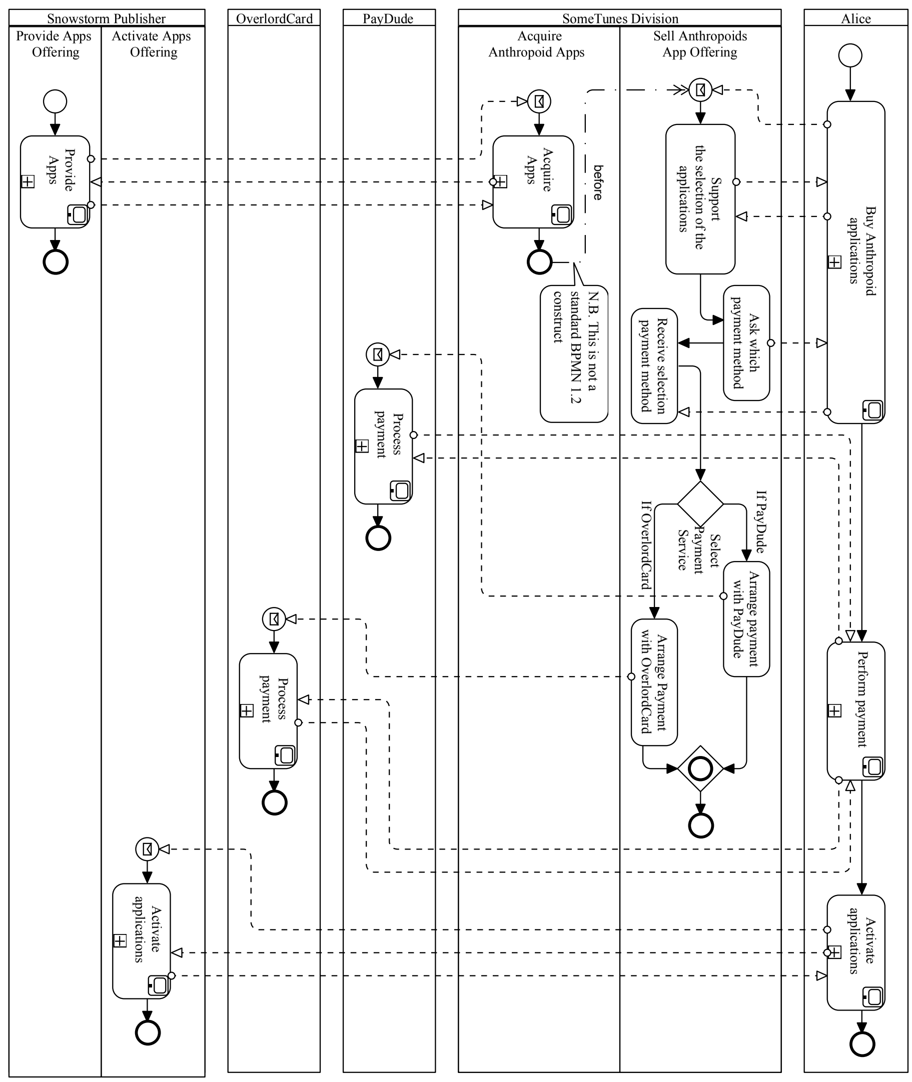


Figure 4: A BPMN process that specifies the operational details of the "Buy Anthropoid Applications Providing"

in terms of BPMN from a service network model are trivial workflows that contain subprocesses, e.g. in the case of the lanes of PayDude, OverlordCard and Snowstorm Publisher. The message exchanges connecting the workflows of the participants are also approximated. We assumed that whatever may be the logic of the workflows of PayDude, OverlordCard and Snowstorm Publisher, they would engage in message-based conversations with SomeTunes and Alice. We represent these message-based interactions as message flows in Figure 4.

5.2.2 Service Network Constructs not Explicitly Mapped to BPMN

Service providings and their dependencies are implicitly represented in BPMN by the interactions among the workflows of service requests and offerings of the participants. For example, the service providing "Providing of Applications" is represented in BPMN by the interactions between the "Sell Anthropoid Apps Offering" lane of SomeTunes and Alice's "Buy Anthropoid Apps" request.

In similar fashion to service providings, participant internal dependencies and the associated temporal relations are implicitly modelled in the workflows that represent the service requests and offerings of one participant. The temporal dependencies between workflows that do not interact with each other cannot be modeled in BPMN. This is for example the case of the "before" temporal dependency between "Acquire Anthropoid Apps Request" and "Sell Anthropoid Apps Offering". For explanatory purposes we have modeled this temporary dependency using an informal notation (shown in the BPMN model).

BPMN cannot represent some of the constructs of service networks, namely business relations and their contracts, and the contracts associated with the service providings. We underline that this is not an issue of service network models, BPMN, or their interaction, but it is merely a consequence of the differences of their scopes. BPMN focuses on the operational dimension of a business process, i.e. the ordering of activities in the workflows. Contracts, instead, pertain to the legal aspect of business processes. Some aspects of contracts, such as the deadlines for the provisioning of service, can be reflected in the operational specification of business processes, e.g. using timers in BPMN. Other type of contractual obligations like non-competition clauses find no natural representation in BPMN.

6 Related Work

Service networks are a multidisciplinary subject, and authors from various communities have been investigating them from different perspectives. A comprehensive overview of the related work on the various aspects of service networks would require a survey. For reasons of space we limit ourselves to the modelling notations for service networks that have been proposed so far.

Allee proposes a graph-based notation to model value flows inside a network of business entities [Allee 00]. The value flows from an entity to the other through the exchange of goods and services, knowledge (e.g. customer data), or intangible benefits (for example improved branding). The proposed notation takes into account only the value flows among the business entities, and does not consider either other types of business or technical relations, hence limiting the synergies with the technology stack and the related practices.

In the same lines of Allee's work, Gordijn and Akkermans propose *e3value*, a sophisticated graphical notation to describe the economical aspect of value propositions of e-business models [Gordijn 01]. Other works in the area of value flow modelling are, e.g., the contributions of Biem and Caswell [Biem 08], and Andersson et al. [And. 05]. Our work is orthogonal to the ones on value flows. Potentially, value models can be super-imposed to our service network models in order to, for example, estimate the profitability of the networks. Moreover, the analysis methods and change operators for service networks could be correlated with their equivalents for value flows, thus bringing together the operational and value aspects of service networks.

Steen et al. propose Rapid Service Develepment (RDS), a notation to describe interactions of actors in networked enterprises [Steen 02]. Instead of dealing with services, they model exchanges of information, goods and money, collectively referred to as "items". Items and exchanges over bilateral channels that connect the actors that perform the exchanges. Our formalism and RDS have considerable differences in their scopes. RDS focuses rather on the operational side of service networks by modelling the behaviour of the participants using a basic workflow notation – an aspect that we consider out of the scope of a service network model, and delegate to dedicated notations like BPMN. Moreover, RDS does not consider the contracts that bind the participants, which we find of great importance in service networks.

The work of [Blau 09] proposes a formalism for modeling Service Value Networks (SVNs) as a demand-driven, ad-hoc network of providers and their service offerings. Each SVN model targets the satisfaction of one (complex) service request. The SVN is represented as a graph that describes all the feasible combinations of service offerings that may satisfy the given service request. The best alternative is then selected by e.g. aggregated price. The scope of our work and the SVNs is different, in that we support the modeling of business relationships among participants, while [Blau 09] treats only the selection process of potential service compositions for the satisfaction of a service request. In this respect, the SVN selection mechanism could be applied to highlight potential short-term ad-hoc service providing in the service networks.

The aspect of business relationships among participants has been investigated by Telang and Singh, who propose a formulation of service networks –

called business models – defined as sets of business relationships among agents (that are equivalent to our participants) [Telang 09]. In their work the agents have goals and capabilities, i.e. abstractions of tasks that the agents can perform. Each business relation imposes commitments on two or more agents that are satisfied by the execution of the required tasks. Business model commitments can be manipulated using change operators such as creation, delegation, detachment and cancellation. On the basis of their formalization of business models, the authors investigate four recurring patterns in business models: outsourcing, unilateral commitment, commercial transaction, and standing service contract. Assuming process models specified by the means of UML sequence diagrams, the authors define methods for verifying (1) the satisfactions in the process models of the commitments specified in a business model, and (2) the achievement of the actors' goals. In a sense, agents, commitments and capabilities can be mapped to participants, service providing and their contracts, and service offerings respectively. With respect to our work, the business models of Telang and Singh focus on goal modelling, whereas we provide more flexible constructs to model the service network-level interactions among the participants. In principle it would be possible to bridge between the two approaches and bring goal modelling to our formalism for service networks. However, this would compromise the separation of concerns that we wish to infuse in our approach by trespassing the domain of business strategy modelling.

7 Summary

Service networks are a promising multidisciplinary field that has recently attracted a considerable amount of interest and research efforts. In this paper we have discussed aspects of service networks modelling in relation with the practices of Business Process Management (BPM) and Service Oriented Architecture (SOA). We have presented a formalism to model service networks with the emphasis on software services and the interplay of service requests, offerings and providings among the participants. The concepts presented in this work have been exemplified using a running example depicting the service network surrounding a fictional online media store.

We have underlined the paramount relevance of two aspects of the (future) practice of service networks modelling: (1) analysis and (2) change management. The state of the art of analysis methods for service networks is still in its infancy and it is currently mostly focused on the value flows among the participants. However, more refined and wide-reaching analysis methods are needed in order to render service networks into a valuable tool for supporting strategic business decisions and the management of the enterprises. In particular, we believe that the future research will need to investigate the optimization of aspects of service networks stemming from both the technical and economical perspectives.

Moreover, the optimization methods will necessarily support both local (i.e. a subset of the participants) and global (i.e. optimizing the entirety of the network) perspectives.

The ultimate goal of analysis methods is to outline what to modify service network models to reach a goal (e.g. value-flow optimization). However, to apply those modifications to actual service networks and the technology infrastructure that realizes them, there is the need of a comprehensive approach to the change management of service network. Such change management will have to embrace and deal with all the technological layers of service networks and their implementations. In this work we have laid the foundations for the change management of service networks by investigating the correspondences between the constructs of the service networks modelling formalism we proposed and the ones provided to business process modelling by the Business Process Modelling Notation (BPMN) version 1.2.

Acknowledgements

The research leading to these results has received funding from the European Community's Seventh Framework Programme under the Network of Excellence S-Cube - Grant Agreement n° 215483.

References

[And. 05] Birger Andersson, Maria Bergholtz, Ananda Edirisuriya, Tharaka Ilayperuma, and Paul Johannesson. "A declarative foundation of process models." In Oscar Pastor and João Falcão e Cunha, editors, *CAiSE*, volume 3520 of *Lecture Notes in Computer Science*, pages 233–247. Springer, 2005.

[Andrikopoulos 08] Vasilios Andrikopoulos, Salima Benbernou, and Mike P. Papazoglou. "Managing the evolution of service specifications." In Bellahsene and Léonard [Bellahsene 08], pages 359–374.

[Allen 83] James F. Allen. "Maintaining knowledge about temporal intervals." *Commun. ACM*, 26(11):832–843, 1983.

[Allee 00] Verna Allee. "Reconfiguring the value network." *Journal of Business Strategy*, 21(4), July 2000.

[Allee 08] Verna Allee. "Value network analysis and value conversion of tangible and intangible assets." *Journal of Intellectual Capital*, 9, No. 1,:pp. 5–24, 2008.

[Biem 08] Alain Biem and Nathan Caswell. "A value network model for strategic analysis." In *HICSS*, page 361. IEEE Computer Society, 2008.

[Barros 06] Alistair P. Barros and Marlon Dumas. "The rise of web service ecosystems." *IT Professional*, 8(5):31–37, 2006.

[Barros 05] Alistair P. Barros, Marlon Dumas, and Phillipa Oaks. "Standards for web service choreography and orchestration: Status and perspectives." In Christoph Bussler and Armin Haller, editors, *Business Process Management Workshops*, volume 3812, pages 61–74, 2005.

[Bitsaki 08a] Marina Bitsaki, Olha Danylevych, Willem-Jan van den Heuvel, George Koutras, Frank Leymann, Michele Mancioppi, Christos Nikolaou, and Mike P. Papazoglou. "An architecture for managing the lifecycle of business goals for partners in a service network." In Petri Mähönen, Klaus Pohl, and Thierry Priol, editors, *ServiceWave*, volume 5377 of *Lecture Notes in Computer Science*, pages 196–207. Springer, 2008.

[Bitsaki 08b] Marina Bitsaki, Olha Danylevych, Willem-Jan van den Heuvel, George Koutras, Frank Leymann, Michele Mancioppi, Christos Nikolaou, and Mike P. Papazoglou. "Model transformations to leverage service networks." In George Feuerlicht and Winfried Lamersdorf, editors, *ICSOC Workshops*, volume 5472 of *Lecture Notes in Computer Science*, pages 103–117. Springer, 2008.

[Blau 09] Benjamin Blau, Jan Kramer, Tobias Conte, and Clemens van Dinther. "Service Value Networks." In *IEEE International Conference on E-Commerce Technology*, pp. 194–201, 2009.

[Buford 01] John Buford. "Telecommunication Services and Service Management Challenges." Journal of Universal Computer Science, 7(5):355–365, 2001.

[Busi 05] Nadia Busi, Roberto Gorrieri, Claudio Guidi, Roberto Lucchi, and Gianluigi Zavattaro. "Choreography and orchestration: A synergic approach for system design." In Boualem Benatallah, Fabio Casati, and Paolo Traverso, editors, *ICSOC*, volume 3826 of *Lecture Notes in Computer Science*, pages 228–240. Springer, 2005.

[Bellahsene 08] Zohra Bellahsene and Michel Léonard, editors. *Advanced Information Systems Engineering, 20th International Conference, CAiSE 2008, Montpellier, France, June 16-20, 2008, Proceedings*, volume 5074 of *Lecture Notes in Computer Science*. Springer, 2008.

[Camarinha-Matos 04] Luis M. Camarinha-Matos. *Virtual Organizations: Systems and Practices*. Springer-Verlag TELOS, Santa Clara, CA, USA, 2004.

[Camarinha-Matos 06] Luis M. Camarinha-Matos and Hamideh Afsarmanesh. "Towards a reference model for collaborative networked organizations." In *Information Technology For Balanced Manufacturing Systems (BASYS'06)*, pages 193–203, 2006.

[Caswell 08] N. S. Caswell, C. Nikolaou, J. Sairamesh, M. Bitsaki, G. D. Koutras, and G. Iacovidis. "Estimating value in service systems: a case study of a repair service system." *IBM Syst. J.*, 47(1):87–100, 2008.

[Daskalopulu 99] Aspassia-Kaliopi Daskalopulu. *"Logic-Based Tools for the Analysis and Representation of Legal Contracts"*. PhD thesis, Imperial College London, 1999.

[Dang 06] Jiangbo Dang and Michael N. Huhns. "Concurrent multiple-issue negotiation for internet-based services." *IEEE Internet Computing*, 10(6):42–49, 2006.

[Decker 08] Gero Decker, Oliver Kopp, Frank Leymann, Kerstin Pfitzner, and Mathias Weske. "Modeling service choreographies using bpmn and bpel4chor." In Bellahsene and Léonard [Bellahsene 08], pages 79–93.

[Dustdar 05] Schahram Dustdar and Wolfgang Schreiner. "A survey on web services composition." *IJWGS*, 1(1):1–30, 2005.

[Gordijn 01] Jaap Gordijn and Hans Akkermans. "Designing and evaluating e-business models." *IEEE Intelligent Systems*, 16(4):11–17, 2001.

[Kritikos 09] Kyriakos Kritikos and Dimitris Plexousakis. "Mixed-integer programming for qos-based web service matchmaking." *IEEE T. Services Computing*, 2(2):122–139, 2009.

[Meshkova 08] Elena Meshkova, Janne Riihijärvi, Marina Petrova, and Petri Mähönen. "A survey on resource discovery mechanisms, peer-to-peer and service discovery frameworks." *Computer Networks*, 52(11):2097–2128, 2008.

[Maglio 06] Paul P. Maglio, Savitha Srinivasan, Jeffrey T. Kreulen, and Jim Spohrer. "Service systems, service scientists, ssme, and innovation." *Commun. ACM*, 49(7):81–85, 2006.

[Maglio 09] Paul P. Maglio, Stephen L. Vargo, Nathan Caswell, and Jim Spohrer. "The service system is the basic abstraction of service science." *Inf. Syst. E-Business Management*, 7(4):395–406, 2009.

[Osterwalder 04] Alexander Osterwalder. *"The Business Model Ontology - a proposition in a design science approach"*. PhD thesis, Université de Lausanne, 2004.

[Papazoglou(07)] Mike P. Papazoglou. *"Web Services: Principles and Technology"*. Prentice Hall, 2007.

[Peltz 03] Chris Peltz. "Web services orchestration and choreography." *IEEE Computer*, 36(10):46–52, 2003.

[Papazoglou 07a] Mike P. Papazoglou, Paolo Traverso, Schahram Dustdar, and Frank Leymann. "Service-oriented computing: State of the art and research challenges." *IEEE Computer*, 40(11):38–45, 2007.

[Papazoglou 07b] Mike P. Papazoglou and Willem-Jan van den Heuvel. "Service oriented architectures: approaches, technologies and research issues." *VLDB J.*, 16(3):389–415, 2007.

[Papazoglou 08] Mike P. Papazoglou, Paolo Traverso, Schahram Dustdar, and Frank Leymann. "Service-oriented computing: a research roadmap." *Int. J. Cooperative Inf. Syst.*, 17(2):223–255, 2008.

[Steen 02] Maarten W. A. Steen, Marc M. Lankhorst, and R. G. van de Wetering. "Modelling networked enterprises." In *EDOC*, pages 109–119, 2002.

[Telang 09] Pankaj R. Telang and Munindar P. Singh. "Business modeling via commitments." In *SOCASE*, pages 111–125, 2009.

[van den Heuvel 08] Willem-Jan van den Heuvel. "Survey on business process management." Deliverable PO-JRA-2.1.1, S-Cube Consortium, July 2008.

[Weerawarana (05)] Sanjiva Weerawarana, Francisco Curbera, Frank Leymann, Tony Storey, and Donald F. Ferguson. *"Web Services Platform Architecture: SOAP, WSDL, WS-Policy, WS-Addressing, WS-BPEL, WS-Reliable Messaging and More"*. Prentice Hall PTR, Upper Saddle River, NJ, USA, 2005.

[Wetzstein 08] Branimir Wetzstein. "Overview of the state of the art in composition and coordination of services." Deliverable PO-JRA-2.2.1, S-Cube Consortium, July 2008.

[Zirpins 09] Christian Zirpins and Wolfgang Emmerich. "Pattern-based e-service modelling for virtual service enterprises." *Service Oriented Computing and Applications*, 3(1):65–98, 2009.

Performance Analytics and Design of Service Networks: A Systems Dynamics Approach*

Willem-Jan van den Heuvel[1], Martin Smits[1] and Christos Nikolaou[2]

[1]European Research Institute in Service Science & Department of Information Systems, Tilburg University, PO Box 90500, 5000 LE, Tilburg, The Netherlands
wjheuvel@uvt.nl, m.t.smits@uvt.nl
[2]Transformation Services Lab, University of Crete
PO Box 71003, Heraklion, Greece
nikolau@tsl.gr

Abstract. Over the last years, several analysis and design methodologies have emerged for engineering SOA applications. However, none of these methodologies can effectively cope with the increased level of complexity and dynamics that come with service networks. In addition, and even more problematically, existing methodologies fall largely short in assisting application designers in evaluating the impact of design decisions on the performance of the service-enabled applications and the business processes they implement.

In this paper we introduce a performance analytics model and associated toolset that is grounded on system dynamics to assist service designers in making educated decisions about network design options by allowing them to calibrate performance of end-to-end processes that live within the network with supporting service resources, including software services and human-operated services.

1. Introduction

The growth of services economies, coupled with the evolution of powerful digital communication networks - which we tend to associate with the Internet - help transform service companies from local businesses to globally integrated service networks [1, 2], also referred to as service networks. Service networks are open, complex and fluid, socioeconomic systems of organizations and processes that break away from classical hierarchies of knowledge and power, to accommodate the co-production of new knowledge and services through organic peer-to-peer interactions. For this purpose, service networks embody end-to-end processes that are layered on services that providers provide and clients consume, and that may be connected at a global scale.

Service oriented computing is heralded as a natural candidate to develop and manage service networks as choreographed, event-driven software and human-operated services that collectively realize end-to-end (transactional) processes [3].

Over the last years, several analysis and design methodologies have emerged for engineering service-enabled applications. Prominent examples include: Service Lifecycle Process [4],

* The research leading to these results has received funding from the European Community's Seventh Framework Program under the Network of Excellence S-Cube grant agreement 215483.

Service-Oriented Modeling Framework, Mainstream SOA Methodology (MSOAM) [5], and, Service-Oriented Modeling and Architecture (SOMA) [6]. Unfortunately, however, none of the above methodologies were designed with service networks in mind, while embracing the closed-world assumption that assumes that applications have clear boundaries and will be executed in fully controlled, homogeneous, predictable and stable execution environments [19]. These methodologies thus cannot be expected to effectively cope with the increased levels of complexity and dynamicity of service networks that typically exhibit non-linear, non-deterministic and unpredictable behavior. In addition, and even more problematically, existing SOC development methodologies largely fall short in assisting application designers in evaluating the impact of design decisions on the performance at the level of service-enabled applications and the business processes they support. *Performance* of service networks refers to their ability to accomplish service level objectives at the level of service resources, including human-operated and software services, and, strategic business objectives at the level of the end-to-end processes that live within them.

The main aim of this paper is to develop and partially validate an analytical model to guide and foster the logical design of service networks. The analytical model –supported by a tool- helps service engineers in predicting the impact of design decisions on performance of service networks. Relying on our analytical model, service architects may methodically assess the performance trade-off of different process configurations and alternate resource allocation schemes. The outcome of such predictive strategic planning exercises may not only be useful to ascertain acceptable performance of the network, but also be used as a baseline for business activity monitoring tools, business process monitoring tools and other monitoring platforms used within the network.

Before we introduce the performance analytical model for service network engineering, we will first further refine the notion of performance analytics in the context of service network engineering in section two after which we will introduce a simple, yet realistic running example that is drawn from the domain of automotive in section 3 and that we will use to further explore and validate our analytical model. Section 4 then introduces the service performance analytics model that is grounded on a special branch of simulation, named System Dynamics. Lastly, section 5 summarizes the key finds and plots the path for future research.

2. Performance Analytics in Service Network Engineering

A service-oriented design and development methodology for service networks is typically based on an iterative and incremental process. Many SOA lifecycle models have been introduced (see section 1), embodying the well-known phases of software engineering lifecycle methodologies.

We herein propose a methodology for engineering service networks that refines existing lifecycle models, and comprises five main phases that may be traversed iteratively (see Figure 2) catering for service network design centered around performance analytics. The phases are: modeling (network analysis and design), implementation and testing, deployment and execution, analyzing and monitoring, and measuring and optimizing. The first phase aims at producing a logical and physical design of the service network. Firstly, the service designer starts with *conceptualizing* the network in terms of the network partners, the end-to-end processes that live within the network, and choreographed software/human services that implement them. The logical design typically entails abstract models of the process and service choreography rendered in conceptual notations such as the BPMN-2.0 Business Process Diagram, Collaboration Diagram and Choreography Diagram. Ideally, these models are calibrated to meet performance requirements for the end-to-end process in terms of Key Performance Indicators (KPIs), and, supporting service resources in terms of Quality-of-Service (QoS). During the second step, the logical design of the service network will be refined into a physical design, typically relying on the well-know standards from the WS-stack, such as WS-Policy, WSDL and BPEL. Service network implementation and testing involves coding or identifying reusable service resources and choreographing them into end-to-end processes using the physical specifications. It also involves testing coded services and processes for functional correctness and completeness as well as for interoperability. The service network deployment and execution phase continues enforcing the business model for service provisioning; addressing issues service metering, service rating and service billing. Once the provisioning model has been established, the service network may be deployed recursively, involving deployment of human-operated and software (Web) services by all partners in the service network. Execution includes the actual binding and run-time invocation of the deployed choreographed services. The next phase involves monitoring and analyzing the execution of the service network, resolving potential process and service anomalies including unforeseen interoperability conflicts. Lastly, progress of executing end-to-end processes in the service network are measured against performance metrics, such as KPIs, and optimized on an as-needed basis.

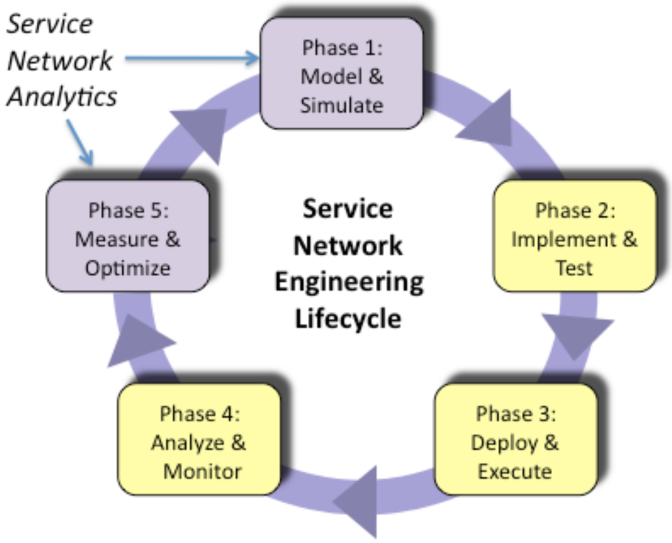


Figure 1 Service Network Engineering Lifecycle

We propose to adopt a lifecycle model approach of continuous invention that considers multiple realization scenarios for end-to-end processes and Web/Human services that take into account both technical and business performance concerns in service networks. Basically, we suggest to leverage phase 1 and 5 of conventional approaches with two types of performance analytics of service networks: design-time and runtime (see the purple rounded boxed in Figure 1).

Design time service analytics utilizes conceptualizations, the logical models, of service networks to verify their performance against agreed-up service levels of partner-level and network-level processes. Runtime service analytics study event logs that are provided by service monitoring tools, and measure progress of end-to-end processes against performance metric, and proactively pinpoint areas for process improvement and troubleshoot the root-cause of bottlenecks. Due to reasons of space and scope, only design-time performance analytics will be considered in the remainder of this article.

3. Motivating Scenario

The motivating scenario is based on [7] and revolves around a car repair service network that basically links four types of participants: an Original Equipment Manufacturer (e.g., Volvo), OEM-franchised Car Dealers, Third Party Suppliers (TPS), and, Clients.

OEM-franchised car dealers may service and repair cars for their clients. Both activities require a car parts catalogue to ensure that repairs can be performed efficiently either in the replacement of parts or repairing after accidents. The car catalogue facilitates efficient installation, operation and lifecycle maintenance of intricate products describing detailed part information that can be fully integrated with other service applications supporting customer support processes, human resource management, and other service provisions. The quality of the OEM parts, the OEM car catalogues, and OEM support services influences the fraction of parts from OEM or TPS. Figure 2 depicts a simplified version of the choreography for car repair in BPMN 2.0 syntax.

Vehicles are booked in 15-minute time intervals to allow customers to discuss their needs with fully trained automotive engineers. The engineers then inspect the car on the hoist and diagnose and report the car service requirements that may include replacing teardowns, warranty replacements and collision repairs. On the basis of the car diagnosis, a cost estimate will be computed and communicated to the client for authorization. Once authorized the automotive engineer will scrutinize failure symptoms, detect faulty parts, order parts and perform the repair.

Ordering parts is a complex process that involves asking advice from expert technicians from the OEM, including acquiring information about parts under warranty, and getting approval from the dealer's part manager. The part manager then checks local inventory for the required part, and if necessary checks the stock at the OEM or supplier stocks, and eventually places an order. The part manager may either use third-party suppliers or suppliers from certified supply-chain suppliers. The automotive engineers spend on average one hour/day determining which parts to

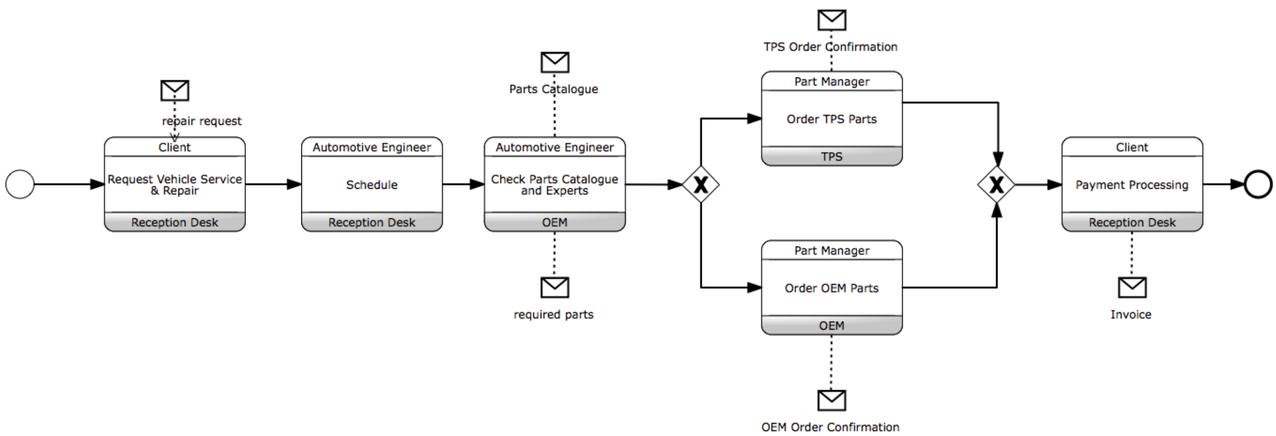


Figure 2 BPMN Choreography Model of Car Repair Case

order, whilst the part manager loses roughly 30 mins/day checking local inventory and ordering parts that are out of stock.

While logically designing the car repair service network, the service engineer faces many design challenges about which network partners to involve, how to abstractly choreograph their services into end-to-end processes, and which IT or human services to utilize. Each design decision may affect performance at the level of the (end-to-end) processes as well as the level of the service resources.

In the context of the running example, the service engineer needs to decide for example on which design option yields the optimal customer satisfaction (performance) for the service network: reinforcing human help desk services of OEM, e.g., through additional human resources, or automating the OEM parts catalogue with Web services for faster and more accurate information about car parts.

Both design options, and their ramifications for the performance at the level of the service resources and (end-to-end) processes have been illustrated in Figure-3. As this Figure tries to illustrate the mapping between performances at both levels –the mapping function- signifies the key challenge. In particular, the dotted directed lines in Figure 3 depict mapping functions from the QoS specification of the two design options to the aggregated Customer Satisfaction metric associated to the check parts process. Note that for reasons of simplicity, we have defined an index variable (e.g., QoS-OEM=1 for the base option), which can be decomposed into sub-indexes, e.g., latency and uptime. The mapping function aggregates quality of service of operational software and human-operated services, into strategic, process-related customer satisfaction, signifying a positive feedback loop. We have found evidence in scientific literature that similar assumptions have worked effectively for simulations. In particular in [8] an approach is introduced and validated for Web services management, modeling service request processing based on the same assumption.

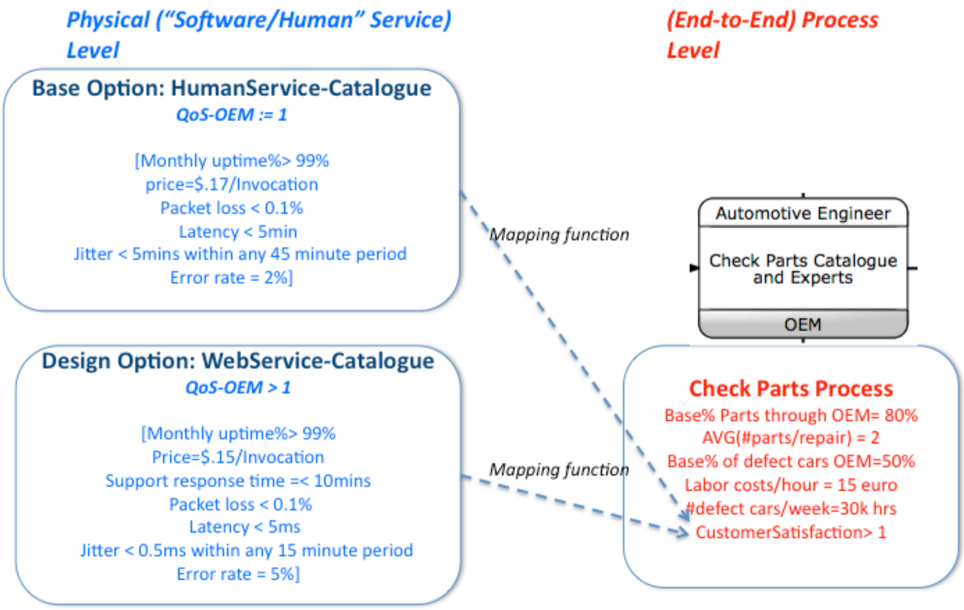


Figure 3 Design options in the Car Repair Network

4. Simulation

Simulation is a powerful, rigorous yet practical suite of methods and tools that help to analyze and predict qualitative and quantitative effects on service systems. Simulation not only helps to better understand and manage service systems at large, but also the processes that embody them as well as their supporting information systems.

Simulation plays a critical role in the analysis, design and management of service networks [2, 18]. In particular, simulation helps to identify performance leakages, better understand and explore the impact of change scenarios, to test and verify compliance towards resource constraints and business rules and goals, and to assess risk by examining operational impact, i.e., timeliness and quality, on the network.

Two mainstream simulation models have emerged that combine several of the above basic simulation models, viz. discrete-event dynamic systems (DEDS) simulation models and system dynamic (SD) simulation models. DEDS deals with individual events, such as a customer request or the shipment of a product, and can deal with uncertainties. SD was developed in the 1950s [9] and promotes a dynamic, continuous yet deterministic simulation approach from an aggregated, non-discrete perspective. In its basic form, system dynamics analyzes positive and negative feedback loops and emerging behavioral effects –such as exponential growth or decline– that result from them. Typically, dynamic behavior in service networks manifests itself as oscillating behavior where corrective actions force the network to a steady state where performance is tuned between end-to-end processes and supportive service resource.

In this research, we have adopted system dynamics for the following three reasons. First, performance analytics is "dynamically complex", meaning that (end-to-end) process and service resource design decisions will provoke planned and unplanned consequences, which cannot be easily predicted without the help of a computer simulation model. In addition, the performance analytics problem is long term, meaning that effects of (end-to-end) process and resource design decisions do not appear immediately but only after some weeks/months. Third, while service networks are in fact dynamic systems of systems, it is only natural to conceptualize them in terms of flow processes (end-to-end processes, service processes, resource management) –just like in SD. These three reasons makes simply relying on discrete event simulation –as done by many process modeling simulators- largely inappropriate to measure and tune performance that permeates service networks at the logical and physical level.

System dynamics modeling has been used frequently to solve management problems. Notably, over 1500 publications have been identified to solve management problems with system dynamics in health care. Even more publications deal with policy modeling and supply chain management [13].

5. Service Performance Analytics Model

In this section, we introduce a performance analytics model in support of strategic analysis of service network changes and improvements. For the reasons aforementioned, the performance analytics model is specified in system dynamics, and is exemplified in terms of the running example (see Figure 4) that was introduced in section three. In particular, the SD model amalgamates information taken from the choreography model in Figure 2 with performance related information such as the meta-data that is annotated to the "Check Parts Catalogue and Experts" process step in Figure 3, relying on [7]. The model has been implemented in the

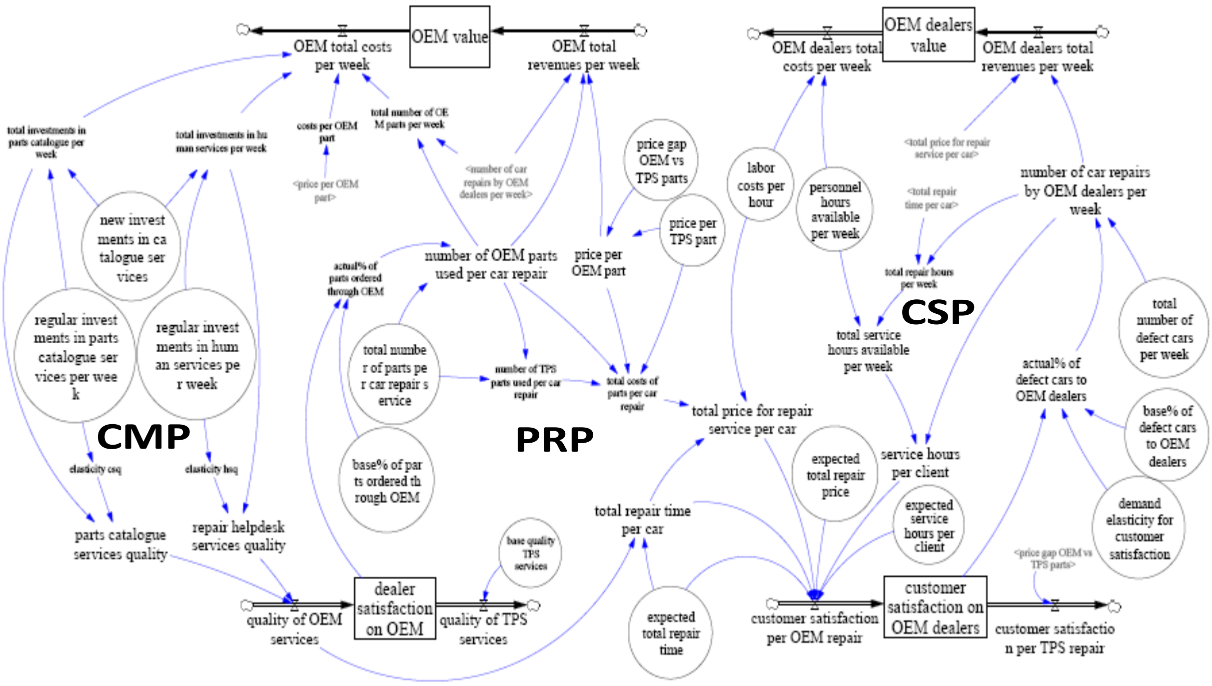


Figure 4. System Dynamics Model of the Car Repair Service Network

VenSim tool[†] relying on the de-facto SD methodology as described in [13], where stocks are represented as rectangles, inflows and outflows by incoming and outgoing directed pipes, valves can control flows, and clouds render sources and sinks. Behind this graphical model lie 85+ mathematical functions, specifying functions of the stock and other dependent (non-circled parameters in the same figure) and independent (circled parameters) variables.

Tables 1 and 2 define the quantitative grounding of the service performance analytics model: Table 1 shows the 17 main inputs of the SD model, including the (single) design decision for the service engineer as specified in Figure 3. Table 2 shows the 12 main outputs (dependent variables) on different actor levels of the model.

The SD model consists of four sections defined around the four stocks in the service network: OEM value (upper left in Figure 4), OEM dealer value (upper right), OEM dealer satisfaction on OEM (lower left), and customer satisfaction on OEM dealers (lower right). Note that, like in a supply chain, the upper sections indicate financial flows (costs and revenues) from right to left and the bottom sections the flow of services from left to right to the end customer. The four sections are logically chained into three processes: the Catalogue Management Process (CMP), the Parts and Repair Process (PRP, cf. Figure 2) and the Customer Support Process (CSP).

OEM value is a stock that accumulates OEM total revenues per week (inflow rate) and OEM total costs per week (outflow rate). OEM value will rise if the OEM total costs decrease or OEM total revenues increase. The model shows that *OEM total costs* are influenced by four variables: investments in parts catalogue services and human services, production costs per OEM part and the total number of OEM parts. *OEM total revenues* are influenced by number of OEM parts used per car repair and OEM price per part and number of car repairs per week.

Dealers' satisfaction on OEM is a stock that increases if OEM parts catalogue services and human services together outperform the quality of TPS services. The quality of OEM services is influenced by the decision whether to leverage catalogue service quality with Web services (new design option) or that of helpdesk services (base option).

[†] http://www.vensim.com/

OEM quality of service and dealer satisfaction on OEM influence the parts and repair process (PRP) through its impact on the total repair time per car and the number of OEM parts used per car repair.
Customer satisfaction on the car repairs of OEM dealers constitutes the third stock in the model. This stock increases if customer satisfaction per OEM repair (inflow) outperforms customer satisfaction per TPS repair (outflow). Customer satisfaction per OEM repair is an index value, calculated from total repair time (versus expected total repair time), total price for repair service per car (versus expected price), and service hours per client (versus norm service hours per client).
Lastly, OEM dealers' value makes up the fourth stock in the model. This stock accumulates OEM dealers' total revenues per week (inflow) and OEM dealer total costs per week (outflow). OEM dealers' total revenues depend on number of car repairs per week and the total price for repair services per car. OEM dealer total costs depend completely on two control variables (labor costs per hour and personnel hours available per week).
The circled variables in the model signify the 17 control variables (independent variables) in the model, as listed in Table 1. For reasons of simplicity, the current model only considers one control variable that can be adjusted by the service engineer: the decision whether or not to design a web service catalogue that improves QoS of the OEM. The base investment for catalogue services is 21k euro per week and 26k euro for human services per week. Based on function-point analysis, e.g., with the COSMIC approach [14], the service engineer can for example study the impact of reallocating, ceteris-paribus, 10k euro from human services for developing the catalogue Web service.

Actor level	Independent (control) variables	Base value	New design
OEM	Investment in software catalogue services pr wk	0 euro	10k eur
	Regular investment in human services p wk	26000 euro (*)	NC (**)
	Regular investments in catalogue services p wk	21000 euro (*)	NC
	Purchase costs per OEM part (% of sales price)	60% (*)	NC
	Price gap for OEM parts (relative to TPS parts)	2 (*)	NC
Car Repair Network	Total number of parts per car repair service	2 (*)	NC
	Base% parts ordered through OEM	80% (*)	NC
	Price per TPS part	15 euro (*)	NC
	Base% of defect cars to OEM dealers	50%	NC
	Total number of defect cars per week	25000 (*)	NC
OEM dealer	Labor costs per hour	50 euro (*)	NC
	Personnel hours available per week	30000 hrs (*)	NC
	Base repair time per car (expected repair time)	2 hours (*)	NC
Customer	Expected total price for OEM repair service	154 euro (*)	NC
	Expected repair time (= base repair time)	2 hours (*)	NC
	Expected service hours per client	0.35 hours	NC
	Demand elasticity for satisfaction	1	NC

Table 1. Control variables in the car service network on four actor levels. (*) based on [2]. (**) NC = no change.

Running this model resulted into table 2. This table explicates that the investments in Web service catalogue leverage OEM QoS (from the normalized base index value to 1.045) leading to higher customer satisfaction (from the normalized base value to 3.3), and also aggregated network value (revenue), pointing towards a Go-decision for the service engineer.

Actor level	Dependent variables	Base value	New design
OEM	Quality of OEM services (index variable)	1	1.045
	Dealer satisfaction on OEM (index value)	1	5.578
	OEM total revenues per week (euro)	612000 (*)	799980
	OEM total costs per week (euro)	414200 (*)	526988
Car Repair Network	Total price for repair service per car	154 (*)	156
	Total repair time per car (hours)	2 (*)	1.9
	Customer satisfaction per car repair (index)	3	3
	Customer satisfaction on OEM dealers (index)	1	3.3
	Total revenues (dealers +OEM) (euro)	66.385.000	83.433.000
OEM dealer	Number of car repairs by OEM dealers p week	12750 (*)	13333
	Total repair hours per week (hours)	25500 (*)	25498
	OEM dealer total revenues per week (euro)	1.965.000 (*)	2.074.000
	OEM dealer total costs per week (euro)	1.500.000 (*)	1.500.000

Table 2. Dependent variables in the car service network on three actor levels. (*) based on [2].

6. Conclusions and Outlook

We believe that performance analytics will become increasingly important to the concept of service networks where service resources and processes can continually morph themselves to respond to environmental demands and changes without compromising on operational and financial efficiencies. This calls for a disciplined approach that can effectively support service engineers in coping with the increased levels of complexity and dynamicity while factoring performance into logical service network design.

In this paper, we have introduced and explored such an approach leveraging the service network engineering lifecycle model with system dynamics. In particular, we have introduced an analytical model that entails a first attempt in predicting the long-term impact of decision options to network performance as well as service resource allocation. In contrast to existing service engineering methodologies, we suggest a methodology that revolves around an analytical model to take into account performance of end-to-end processes and supporting service resources (human and software services) in service networks, stress their calibration, and consider various network design options.

In [8] a system dynamics based approach is successfully applied for the purpose of Web services management. In particular, an autonomic Web service management system is introduced that employs feedback loops to ensure SLA requirements are continuously met. Our approach uses a similar tactic, alleviating the problem of resource (re-) allocation for singular Web service implementations to the level of service networks.

Clearly, the results presented in this article are core results in nature. Improvements and extensions are needed in various directions. Firstly, we plan to further harness the analytical model using several other case studies. Currently, we are studying three case studies from the domain of healthcare and telecom to reinforce the model using actual data. Secondly, we will formalize the mapping of abstract models of service networks in BPMN 2.0 Choreography and Collaboration diagrams to system dynamics models. For this purpose we propose to extend the meta-model that was developed to capture business transactions in service networks with performance related metrics [18]. Lastly, we envision developing techniques and tools for runtime performance analytics. This will imply an integration of our approach with Web service monitors and process mining tools, such as ProIM [14].

References

1. R.C. Basole and W.B. Rouse: Complexity of service value networks: conceptualization and empirical investigation, IBM Systems Journal, vol. 47, nr. 1, pp. 53-70, Jan. 2008.
2. N.S. Caswell et al. : Estimating value in service systems, IBM System Journal, vol. 47, nr. 1, pp. 87-100, 2008.
3. H. Taylor et al.: Event-driven architecture: How SOA enables the real-time enterprise, Addison-Wesley, 2009.
4. SOA Practitioners' Guide Part 3: Introduction to Service Lifecyle. http://www.healthmgttech.com/editorial_whitepages/SOAPGPart3.pdf. 2006
5. Bell, M., Service-Oriented Modeling (SOA): Service Analysis, Design, and Architecture, Wiley, 2008.
6. Arsanjani, A.: Service-Oriented Modeling and Architecture (SOMA), IBM de¬ve¬lo¬per¬Works 2004, http://www.ibm.com/developerworks/webservices/library/ws-soa-design
7. J. Sairamesh et al: Dealer collaboration: transforming the value chain through integration and relationships, Proc. Of the 2004 International Conference on E-Commerce Technology (CEC'04), pp. 325-239. 2004.
8. L. An and J.J. Jeng: Web Service Management using System Dynamics. Proceedings of the IEEE International Conference on Web Services (ICWS'05), pp.347-354, IEEE Press, 2005.
9. Forrester, Jay W.: Industrial Dynamics, Pegasus Communications, 1961.
10.J. Kleijnen and M. Smits: Performance metrics in supply chain management, Journal of Operational Research Society, 54: 507-514, 2003.
11.R. Kaplan, and D. Norton: The balanced scorecard: Measures that drive performance, Harvard Business Review, pp. 71—79, January/February, 1992.
12.SLA Management Handbook, vol. 4, The Open Group, Enterprise Perspective, 2004.
13.J.D. Sterman: Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill, 2000.
14.L. Santillo:Seizing and Sizing SOA Applications with COSMIC Function Points, Proceedings of the 4th Software Measurement European Forum (SMEF 2007), pp. 156 – 165, Rome, May 2007
15.W.M.P. van der Aalst. Trends in Business Process Analysis: From Verification to Process Mining. In J. Cardoso, J. Cordeiro, and J. Filipe, editors, Proceedings of the 9th International Conference on Enterprise Information Systems (ICEIS 2007), pages 12-22. Institute for Systems and Technologies of Information, Control and Communication, INSTICC, Medeira, Portugal, 2007.
16.M. zur Muehlen and R. Shapiro: Business Process Analytics. In: Rosemann,M. et al.: Handbook on Business Process Management, Vol. 2, Springer Verlag, Berlin 2009.
17.Li-jie Jin, Vijay Machiraju, Akhil Sahai: Analysis on Service Level Agreement of Web Services, HP Technical Report, 2003.
18.Heuvel, WJ van den and Papazoglou MP: Toward Business Transaction Management in Smart Service Networks. IEEE Internet Computing. Pp. 70 – 75. IEEE Press. July 2010.
19.Heuvel, WJ van den: Changing the Face of the Global Digital Economy, Smart service systems as a Catalyst for Innovation. Tilburg University Press, November 2009.

Service Network Modeling and Performance Analysis

Manolis Voskakis
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: voskakis@tsl.gr

Christos Nikolaou
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: : nikolau@tsl.gr

Willem-Jan van den Heuvel
European Research Institute in Service Science
Tilburg University
The Netherlands
e-mail: wjheuvel@uvt.nl

Marina Bitsaki
Transformation Services Lab
University of Crete
Crete, Greece
e-mail: bitsaki@tsl.gr

***Abstract*— The growth of service economies coupled with the evolution of information technology have increased the complexity of service companies in a world of interactions and partnerships. We observe that large and vertically integrated firms are replaced by value-creating service networks. A central problem in service network design is to analyze participants' behavior and optimize their value. In this paper we propose a simulation model to evaluate the long-term impact of changes to resources and predict the performance of service networks.**

Keywords- service networks; value optimization; performance analysis

I. Introduction

The growth of service economies coupled with the evolution of information technology have increased the complexity of service companies in a world of interactions and partnerships. We observe that large and vertically integrated firms are replaced by value-creating service networks. Service networks consist of interdependent companies that use social and technical resources and cooperate with each other to create value [1], [2], [3].

"Fig. 1", depicts the anatomy of a service network comprised of five interrelated levels. In particular, the top level defines end-to-end processes connecting service provisions of several service providers; in this case, Original Equipment Manufacturer (OEM), Car Dealers and Clients [4]. In this way a service network can be partitioned into a set of discrete business services that completely process service client requests. "Fig. 1", shows that an end-to-end process such as car repair is subdivided into composite service processes such as diagnosing the problem to be repaired, ordering part replacements and perform the repair. The order process shown in "Fig. 1", is a composition of several atomic services (see corresponding level) such as investigating failure symptoms, identifying parts, ask advise from technicians, and ordering the appropriate (possibly upgraded) parts. Software and human services can be routinely mapped to atomic services, and can be selected, customized and combined into aggregated service applications. Typically, software service applications will be implemented with Web service technologies; however, this does not necessarily have to be the case. Lastly, the software service may be deployed on a software service infrastructure, which may for example be a distributed cloud environment, providing the capabilities required for enabling the development, delivery, maintenance and provisioning of services as well as capabilities that monitor, manage, and maintain QoS such as security, performance, and availability.

Clearly, the trend will be to move to high-value service networks where business process interactions and trends are examined by business process analysts closely to understand more accurately application needs and dynamics, giving rise to new service analytics models and techniques that will help to pro-actively manage services and pinpoint areas for improvement.

Various approaches have been proposed to measure the performance of service networks [5], [6], [7]. Most of the research has focused on describing models that represent inter-organization exchanges. In [5] a quantifiable approach of value calculation is proposed that connects value with expected revenues. In contrast, Biem and Caswell [6] describe building block elements of a value network model and design a network-based strategy for a prescriptive analysis of the value network. Allee [7] provides a systematic way for approaching the dynamics of intangible value realization, interconvertability, and creation.

In this paper we study the impact of strategic changes on the performance both at the level of the network as well as its participants. In particular, we introduce an analytical model and associated simulation tool to optimize value and help analyzing dynamic "what-if" questions such as: what is

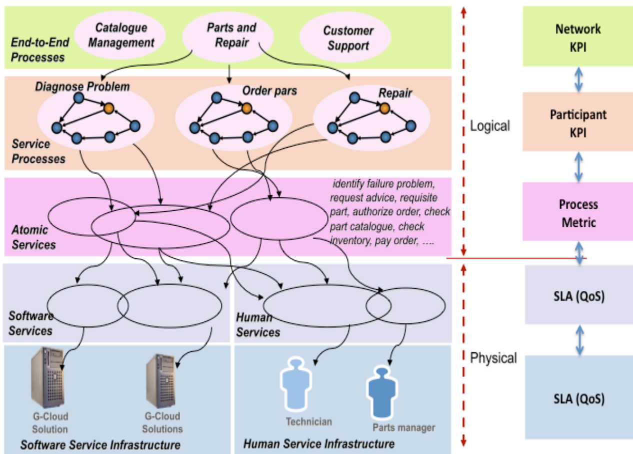


Figure 1. The anatomy of service networks.

the impact of setting optimal – for one participant - prices on the performance of the other participants as well as the entire network? What is the impact on the performance if a new participant suddenly enters the service network? Are there any equilibrium strategies among the participants that eliminate their conflicts of interests?

We observe that participants' value depends on their expected profits. Expected profits express the additional value that will be accrued by the relationship levels a participant develops when it sells goods and services to other participants or to the end customers. This value is related to its intangible assets and on the degree of satisfaction it obtains from its customers. There are many approaches that have been proposed to measure customer satisfaction. In this paper we use the methodology proposed by Fornell et al. known as American Customer Satisfaction Index [8].

We use the System Dynamics approach [9], [10] to analyze the behavior of a complex system (car repair service network) over time. System dynamics tools allow modelers to succinctly depict complex (service) networks, visualizing processes as behavior-over-time graphs, stock/flow maps, and causal loop diagrams. These models can be tested and explored with computer simulation providing for example better understanding of the impact of policy changes (e.g., through animation of (service) systems) and facilities for sensitivity analysis. Examples of such tools include: Dynamo, iThink, PowerSim and Vensim.

In this paper, we have adopted the iThink tool to investigate the fluctuation of value under different circumstances. The results of these simulations provide predictions about the future of the service network in order to increase its adaptability to the changes of the environment and enable network participants to determine the most profitable co-operations and attract new ones. We show that the interactions among the participants of a network force them to reach equilibrium otherwise the network will collapse.

The remainder of this paper is organized as follows: Section II describes the car repair service system. Section III presents the methodology proposed to estimate value in service systems. In Section IV we analyze the case study and run experiments to measure its performance. The results of the simulations are presented in Section V. Finally, in Section VI, we provide some concluding remarks.

II. MOTIVATING SCENARIO

The motivating scenario revolves around a service network that links four types of participants: an Original Equipment Manufacturer (e.g., Volvo), Car Dealers (with repair facilities), Suppliers and Customers. In particular, the scenario considers the end-to-end process "Order & Repair" that was already briefly introduced in the introduction.

The scenario that we will use during the remainder of this article is an extension to [5] and basically looks as follows. OEM-franchised dealers may service and repair cars for their clients. Both activities require a car parts catalogue to ensure that repairs can be performed efficiently either in the replacement of parts or repairing after accidents. The part catalogue facilitates efficient installation, operation and lifecycle maintenance of intricate products describing detailed part information that can be fully integrated with other service applications supporting customer support processes, human resource management, and other service provisions.

The quality of the OEM parts, catalogues, and OEM support services influences how many OEM parts will be ordered and used for a car repair and how many parts will be used from Third Party Suppliers (TPS), and how many customers will go to OEM dealers or to TPS dealers. OEM obtains parts from certified supply-chain suppliers (SCS).

The technicians report the car service requirements that may include replacing teardowns, warranty replacements and collision repairs. On the basis of the car diagnosis, a cost estimate will be computed and communicated to the client for authorization. Once authorized the automotive technician will scrutinize failure symptoms, detect faulty parts, order parts and perform the repair. Ordering parts is a complex process that involves asking advice from expert technicians from the OEM, including acquiring information about parts under warranty, and getting approval from the dealer's part manager. The part manager then checks local inventory for the required part, and if necessary checks the stock at the OEM or supplier stocks, and eventually places an order. The part manager may either use third-party suppliers or suppliers from certified supply-chain suppliers.

III. THE MODEL

In this section, we introduce our service performance analytics model in support of strategic analysis of service network changes and improvements. Theorizing on service networks, and particularly performance analysis, can be addressed from multiple and often complementary perspectives. In our work, we propose a methodology to calculate value in service systems. In contrast with the theories of value that already exist, we focus on the dynamic environment in which service networks emerge, since connectivity and profitable cooperation are the main sources of creating value. We use our model to investigate network profitability and give answers to the following:

- Determine the conditions under which it is profitable for a firm to participate in the network and identify the factors that influence its value.
- Identify key stone participants (participants that create the most value for the network).
- Determine participants' optimal strategic decisions (cooperating with someone or not, joining the network or not, etc).

We consider the service network as a set of participants connected through transfer of offerings that delivers value to them. All offerings are treated as services that are composed by participants' interactions and co-operations to provide a final service to a set of end customers. Let p_{ij} denote the price participant i charges participant j for offering its services and r_{ij} denote the service time of the interaction between participants i and j. Price and time are the main parameters that affect customer satisfaction which is in turn the corner-stone for calculating value as we will see below.

A. Customer Satisfaction

Customer satisfaction measures the willingness of end customers to buy the services offered by the network and influences the increase or decrease of new entries. The calculation of satisfaction $SAT_{ij}(T_N)$ of participant j for consuming services from participant i at the end of the time interval $[T_{N-1}, T_N]$ for our model is a variation of the American Customer Satisfaction Index (ACSI) [8] and basically described as follows. ACSI is operationalized through three measures: q_1 is an overall rating of satisfaction, q_2 is the degree to which performance falls short of or exceeds expectations, and q_3 is a rating of performance relative to the customer's ideal good or service in the category. We quantify the above measures using the following formula:

$$q_k = [(\beta_k/p_{ij})0.6 + (\gamma_k/r_{ij})0.4],\ k=1,2,3, \qquad (1)$$

where [x] denotes the integer part of x and β_ks, γ_ks are the parameters that determine the effect of price p_{ij} and time t_{ij} respectively on q_k. Then, customer satisfaction is given by:

$$SAT_{ij}(T_N)=(w_1q_1+w_2q_2+w_3q_3-w_1-w_2-w_3)/(9w_1+9w_2+9w_3), \qquad (2)$$

where w_k are weights that indicate the importance of each measure q_k.

B. Participants' Value

We consider that an economic entity within a service network has value when it satisfies the entity's needs and its acquisition has positive tradeoff between the benefits and the sacrifices required. We emphasize on the gains or losses captured by the relationships between participants in order to compute value. Our focus is on the methodology in [5], but with a different view of the utilization of relationships between the participants. We define the expected profits $Ep_{ij}(T_N)$ of participant i due to its interaction with participant j to be the expected value of participant i in the next time interval $[T_N, T_{N+1}]$ increased (or decreased) by the percentage change of the expected satisfaction $ESAT_{ij}(T_N)$ in the next time interval and is given by:

$$Ep_{ij}(T_N)=(ESAT_{ij}(T_N)/ESAT_{ij}(T_{N-1}))(ER_{ij}(T_N)-EC_{ij}(T_N)), \qquad (3)$$

where $ER_{ij}(T_N)$ and $EC_{ij}(T_N)$ are the expected revenues and costs respectively for the next time interval. Thus, the value $V_i(T_N)$ of participant i at the end of time interval $[T_{N-1},T_N]$ is the sum of its revenues and the expected profits minus the costs that come from its relationships with all other participants. The total value of the network is the sum of the value of each participant.

C. The Mechansim for Calculating Value

In this subsection we present our value-based model that provides a mechanism to calculate value divided in various hierarchical levels. "Fig. 2" (generated by iThink) shows the upper level of the hierarchy and visualizes the basic elements of our framework. We use the example of Section II to simplify our description. Each node represents a module that calculates the value of a participant. Arrows represent dependencies between modules. Each module encloses a sub-system that calculates the value of the module (second hierarchical level). Complex variables inside the module are presented as modules too. "Fig. 3" shows the dealer's value calculation process. The green arrows show the impact a module has on another module (e.g. dealer's expected profits increase as dealer's revenues increase). The module dealer's costs in the third hierarchical level is depicted in "Fig. 4".

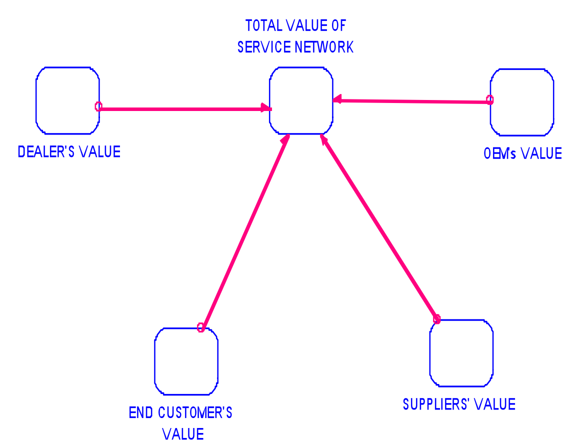


Figure 2. First hierarchical level of value mechanism.

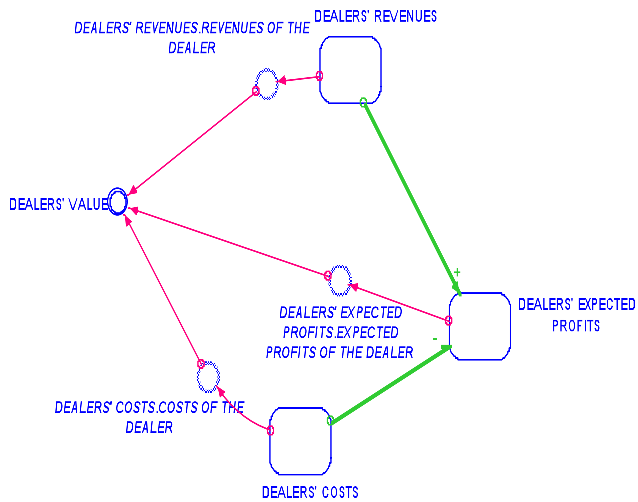


Figure 3. Second hierarchical level – dealer's value.

IV. Simulation Experiments to the Car Repair Service System

We perform simulation experiments to analyze our model making use of 4 scenarios. First, we apply our approach to the car repair service system (Section II) to examine the network's evolution over time. We represent technicians, the parts manager, and the help desk experts as economic entities, each of which is offering its labor as a service to the service system. We measure rates of offerings and payment flows per month over a period of about 30 months. End customer service requests denoted by s are strongly affected by end customer satisfaction, since satisfied customers attract new customers to enter the network. Without loss of generality, we consider that the service requests are produced by the Poisson distribution with mean es being the output of the function:

$$es = -a_1 SAT^2 + a_2 SAT, \quad (4)$$

where $a_2 > 2a_1 > 0$ so that es is an increasing function of SAT in the range [0,1]. (We have chosen "(4)" because the rate of increase of es decreases with respect to SAT.) We also consider that the number of technicians is a function of the number of service requests; we take that the number of technicians increases linearly with the number of service requests. We calculate the value of each participant as a function of price and time and determine its optimal level with respect to price. The equations of revenues and costs for the dealer, the OEM and the suppliers are taken from [5].

Second, we use the transformation of the basic model introduced in [5] in order to cut costs and increase value. Concisely, a solution provider achieves interoperability between participants' information systems through a central portal operated by the OEM. The portal allows everyone to have access to up-to-date information about parts at any time, as soon as this information becomes available to the portal. The gain from the new IT infrastructure is twofold: repair time is reduced resulting in customer satisfaction increase and OEM's mailing costs are eliminated. We apply our methodology to the transformed network to show that the continuous changes of the environment push the network to restructure itself in order to remain competitive. We determine the time interval in which we observe positive effects in profitability in the transformed network compared to the initial one. We also determine which of the participants benefit from the transformation and which not.

Third, we consider a model in which the group of dealers is replaced by a new one that offers more complementarities to the end customers without increasing the mean repair price. This action seems to be profitable due to the increase of the satisfaction of the end customers of the service network. However new dealers have higher costs that may affect service network's value. We examine the value of these dealers and the value of the entire service network provided that OEM chooses to cooperate with them.

Fourth, we investigate Nash equilibrium strategies [11] between OEM and the dealer. We define as a strategy for OEM and the dealers the mean profit rates a and b of selling parts and repair services respectively. Let p_s, p_0, p_d be the mean prices set by the suppliers, OEM and dealers respectively for offering their services. Then it holds that:

$$p_0 = p_s + ap_s = (1+a)p_s, \quad (5)$$

$$p_d = p_0 + bp_0 = (1+b)p_0. \quad (6)$$

We examine the existence of equilibrium strategies considering that the rest of the network participants (apart from OEM and the dealer) do not affect their decisions. We assume that OEM buys parts from certified suppliers at a given price p_s.

V. Results

In this section we present the simulation results from our analysis. First, we compare the basic model with the transformed one.

A . Value Optimization in Basic and Transformed Network

We show the mean repair price p^* that maximizes the dealers' and OEM's value in Table 1.

TABLE I. Comparison Between the Basic and the Transfomed Nework

Value	Model			
	Basic Network		*Transformed Network*	
p*	111 (dealer)	225 (OEM)	116 (dealer)	218 (OEM)
Dealer	51.469.012	34.700.000	46.874.332	34.985.000
OEM	$8500*10^6$	$26793*10^6$	$9100*10^6$	$29990*10^6$

We observe that:

- The dealers' optimal mean repair price in the basic service network is lower than in the transformed service network, since the mean repair time (that affects value) decreases, so the dealer charges his customers less. Consequently, the dealer is forced to increase the mean repair price in order to increase its revenues. Nevertheless, at the optimal mean repair price, dealers' value is less in the transformed network since the customer satisfaction has decreased as well (higher charges).
- OEM's value is much higher in the transformed network than in the basic one. This is explained by the fact that the mean repair time decreases and the customers are more satisfied (at OEM's optimal mean repair price). In addition, OEM in the transformed network has much lower mailing and labor costs.
- In both networks OEM's value at dealer's optimal mean repair price (111 and 116 respectively) is very low compared to OEM's value at his optimal mean repair price. This means that OEM will never be satisfied to offer its services at prices that reach dealer's optimal level.
- Dealers' value at OEM's optimal mean repair price is higher in the transformed network, since OEM's optimal price is lower (218).

Furthermore, the simulation results show that, OEM's value in the transformed network is not higher than that of the basic network from the first month. It dominates after 10-12 months, when both networks offer their final services at their optimal mean repair price ("Fig. 5"). When both networks offer their services at common prices in the range of 80 to 350, the transformed network dominates the basic network at month 8 to 17.

Finally, the total value of the transformed network (32.190.040.300) is maximized at mean repair price 216 and

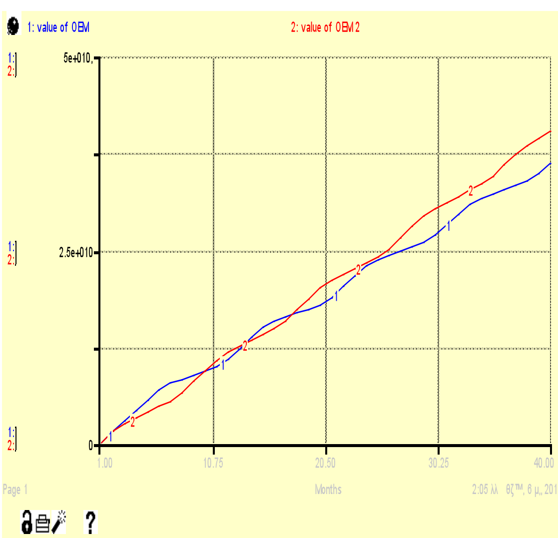


Figure 4. OEM's value in basic and transformed network at common mean repair prices.

is higher than that of the basic network (28.593.400.000) which is maximized at mean repair price 223. This is explained due to the fact that end customers are more satisfied and OEM (the keystone participant) has managed to cut costs at a great extend in the transformed network. Moreover, we see that the optimal mean repair price for both service networks is very close to the optimal mean repair price of OEM, since OEM contributes the largest part of the total value of the network.

B. Sensitivity Analysis of the Mean Repair Price

As the mean repair price increases, the difference between the dealers' value in the basic network and that in the transformed network is smaller. This is justified by the fact that although the service requests decrease the mean repair price increases resulting in a decrease of the total value as shown in Table 2.

TABLE II. DEALERS' VALUE IN BASIC AND TRANSFORMED NETWORKS

Mean Repair Price	Difference of value in two networks
111	13.684.314,52
112	13.389.894,33
113	13.126.171,41
114	12.851.962,76
115	12.658.804,55
116	12.407.585,32
117	12.235.521,63
118	12.036.228,74
119	11.708.826,91
120	11.560.582,04

C. The Impact of New Entries

We call the network with the new group of dealers as the competitive network. We calculate values in the new scenario at mean repair price 216 which is the optimal price for the transformed network. We investigate the impact of the change of dealers letting the price unchanged so that the end customers are motivated to remain in the network. We show that dealers' value (31.527.812) is lower in the competitive network compared to the transformed one (35.481.031), since the new dealers' cost is higher due to the complementarities they offer. In addition, OEM's value increases (from 29.793.000.000 to 31.713.504.020) due to the increase of the service requests. The total value of the network increases from 32.190.040.300 to 32.792.529.000.

From the above we observe that a change in the network that improves its performance may affect positively some participants and negatively others. Naturally, dissatisfied participants abandon the network causing side effects to the others.

D. Participants' Equilibrium Strategies

We perform two experiments in order to investigate strategic interactions and determine equilibrium strategies of OEM and dealers. In the first experiment we calculate OEM's optimal profit rate at a given profit rate for the dealer. Simulations show that when the dealer increases its profit rate (e.g. from 6% to 10%), OEM's optimal choice is to decrease its optimal profit rate (from 24% to 21%). Conversely, if OEM increases its profit rates (e.g. from 14% to 21%), the dealer optimally decreases its profit rate (from 15% to 10%).

The second experiment calculates a set of equilibrium strategies for OEM and the dealer: at dealer's profit rate of 10% the optimal OEM's profit rate equals 21%. Conversely, at OEM's profit rate of 21% the optimal dealer's profit rate equals 10%.

VI. CONCLUSIONS

In this paper we proposed a methodology that estimates value in service systems. We applied this methodology to a car repair service network. We run simulation experiments to maximize the value of each participant and the total value of the network. In addition, we studied the internal relationships that are developed inside the service network and examined the interactions between the participants.

Directions for future work include the study of competitive service networks that form oligopolies in order to increase value. Furthermore, additional work is needed on the estimation of value of intangible assets such as knowledge, sense of community, etc.

REFERENCES

[1] Spohrer, J., Maglio, P., Bailey, J., Gruhl, D., " Steps Towards a Science of Service Systems", Computer 40(1), 71–77, 2007.

[2] V. Allee, "The Future of Knowledge: Increasing Prosperity through Value Networks", Butterworth-Heinemann, Boston, 2002.

[3] J. Gordijn and H. Akkermans, ''Designing and Evaluating E-business Models,'' IEEE Intelligent Systems 16, No. 4, 11–17, 2001.

[4] J. Sairamesh et al: "Dealer collaboration: transforming the value chain through integration and relationships", Proc. of International Conference on E-Commerce Technology (CEC'04), pp. 325-239, 2004.

[5] N.S. Caswell, C. Nikolaou, J. Sairamesh, M. Bitsaki, G.D. Koutras, and G. Iacovidis, "Estimating value in service systems", IBM System Journal, vol. 47, nr. 1, pp. 87-100, 2008.

[6] Biem, A. and Caswell, N, "A value network model for strategic analysis", Proceedings of the 41st Hawaii International Conference on System Sciences, 2008.

[7] Allee, V. "Value Network Analysis and Value Conversion of Tangible and Intangible Assets" Published in Journal of Intellectual Capital , Volume 9, No. 1, 5-24, 2008.

[8] http://www.vernaallee.com/value_networks/Value_Conversion_JIC_online_version.pdf , 2009.

[9] Fornell, C., Johnson, M.D., Anderson, E.W., Cha, J., Bryant, B.E., "The American customer satisfaction index: Nature, purpose, and findings", Journal of Marketing 60, 7–18, 1996.

[10] Forrester, Jay W., "Industrial Dynamics", Pegasus Communications, 1961.

[11] J.D. Sterman, "Business Dynamics: Systems Thinking and Modeling for a Complex World", McGraw-Hill, 2000.

[12] Fudenberg, D., and Tirole, J., "Game Theory". MIT Press, 1991.

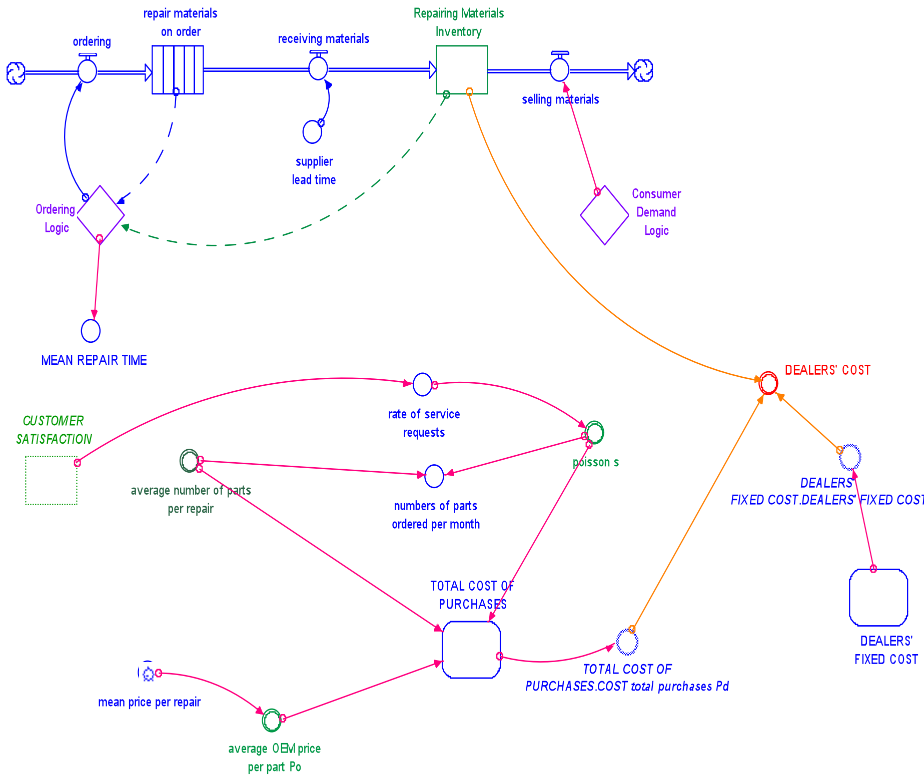


Figure 5. Third hierarchical level – dealer's cost.

Towards A Hybrid Simulation Modelling Framework for Service Networks *

Yan Wang and Willem-Jan van den Heuvel

European Research Institute in Service Science
Tilburg University, The Netherlands
Y.Wang13@uvt.nl W.J.A.M.vdnHeuvel@uvt.nl

1 Motivation

The service sector is an important contributor to modern economies, accounting for more than 50 percent of the gross national product in countries such as Brazil, Germany, Japan, Russia, and the UK, and, making up 80 percent of the US economy [1]. Clearly, the face of the global economy is rapidly being transformed into a global, services-centric economy with networked enterprises transacting and co-creating value on digital infrastructures with a global reach, giving rise to the concept of service networks. Service networks may be defined as systems of service systems that are open, complex and fluid, accommodating the co-production of new knowledge and services through organic peer-to-peer interactions [2]. Resources in service systems may include people, software systems, computing devices and sensor networks, organizations and shared information, such as business rules, regulations, measures and methods. By now, industry has adopted service-oriented computing in conjunction with cloud computing as the de-facto distributed enterprise-computing paradigm for implementing and interconnecting resources in service networks through software (cloud) services.

The design, development, management and governance of service networks have gained much attention in two, largely isolated scientific disciplines. Firstly, service networks have been intensively studied in the discipline of management and business, improving our understanding of their key attributes and classification, their business case, and the operation and management of (integrated) supply chains [3]. Secondly, the engineering of service networks has been recently been picked up by the discipline of service (cloud) computing [4], considering how to design, program, test, deploy and provision software services into aggregated software services.

Clearly, what is needed for service networks to be developed, provisioned and managed in practice, are disciplined methods and tools that are able to take into account, tune and reconcile both technical and business considerations. This paper may be seen as a first, yet critical step in realizing the above vision. In particular, we aim to develop and explore a hybrid service network simulation approach that is able to analyze, optimize and tune the performance of service networks and their resources, including software services and human operated services. Our holistic, hybrid simulation framework will be firmly grounded on pre-existing simulation techniques that have been widely used in process modelling and simulation [4] [5].

The remainder of this extended abstract is basically organized as follows. We will firstly review process simulation techniques in section 2. Section 3 then studies existing hybrid process simulation methods that have been suggested to create synergy

* The research leading to these results has received funding from the European Community Seventh Framework Program under the STREP Cockpit and the Network of Excellence S-Cube grant agreements.

and overcome weaknesses of individual simulation methods. Inspired by these existing hybrid process simulation methods, we then in section 4 introduce and explore a hybrid simulation model and technique for the service networks assist in analyzing and predicting the impact of process changes, resource re-allocations and network re-configurations on the performance of service networks against predefined business metrics such as Key Performance Indicators (KPIs). Our extended abstract is concluded with an exploratory case study in section 5.

2 Business Process Simulation

Developing and managing service networks may benefit tremendously from previous research in business processes engineering that -like engineering service network- is about dealing with the changes either internally within the organization or in the business environment, and may cascade into a cocktail of effects on the human resources (e.g. type and skills), in their involvement (e.g. working hours and schedule), in the process activities (e.g. steps and sequence), and in the supporting technology (e.g. software services) [6]. In service networks, changes originate from multiple interactions among the involved network partners and their resources, their clients and the context in which they live.

Static modelling techniques, such as flowcharting, are not flexible enough to capture the dynamics of these interactions, and unable to provide quantitative outputs for decisions on service network re-configurations and resource re-allocations [7]. In stark contrast to static modelling techniques, simulation can improve our understanding of the dynamic behavior of business process [6]. In particular, simulation, is a useful tool to predict and understand the impact of changes to resource allocations (e.g., a human actor is replaced by a software services) and network configuration (e.g., a network partner outsources part of its work to external partners) to the performance of a service network, considering qualitative and quantitative aspects. In addition, it helps to reach common understanding and consensus amongst various network partners (e.g., public administrators, citizens and service designers) and educate them, without disrupting operational processes. In doing so simulation allows us to iteratively discover, define, refine and improve our knowledge of the principles and laws of service networks, and make more informed and accountable decisions. For this purpose, simulations rely on formal, often mathematical, abstractions of a service system, where specific parameters can be altered so experimenters can study their effects over time.

Over the years, simulation has been extensively studied and applied in various domains including chemistry, physics, sociology, business and management, computer science, and, information systems. Regardless of the application domain, we may discern three dimensions of simulation models [8], namely stochastic/deterministic model, steady-state/dynamic model and continuous/discrete (event) model. Deterministic models denote abstractions whose behavior can be predicted and that do thus not take into account the probabilistic nature of real-world events, assuming everything is certain. Stochastic models are models that do incorporate the element of probability allowing to randomly selecting parameter values. Steady-state models are time-invariant and are typically aggregations or consolidations of data. Dynamic models have normally more practical relevance, as they are able to capture dynamic behavior of systems over time. Continuous simulation models are built on the assumption that changes occur continuously, rather than sporadically. Discrete models on the other hand, model system changes after a specific time interval or incoming event where between any two events/time intervals the service system remains stable.

There are three mainstream paradigms in simulation modelling, viz. System Dynamics (SD), Discrete Event (DE) simulation, and Agent Based (AB) simulation [9].

SD entails 'the study of information-feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decision and actions) interact to influence the success of the enterprise' [10]. In its basic form, SD analyzes feedback loops and the emerging behavioral effects, such as exponential growth or decline, that result from them. SD models populations as discrete actors and conceptualizes processes in terms of aggregated stock and flows and constraint information. Stocks are the accumulation of resources at different states in the processes, which can be material, people, money and so on. The flows connect the stocks and provide the backbone for transporting objects from one stock to another one. The moving rates are determined by the constraint information which comes from the system capacity and business strategy.

DE modelling analyzes system changes after a specific time interval or incoming event where between any two events/time intervals the service system remains stable. DE models are defined in terms of entities, resources and block charts describing entity flow and resource sharing [9]. In DE models, entities (e.g. people, tasks or messages) passively travel through the block of flowcharts, where they could be delayed, stopped, processed, etc. The core difference between SD and DE [11] are (1) DE models tend to include randomness, while as in SD models stochastic noise can be subsumed into an appropriate delay, and (2) DE models are carried out in an open-process structure and SD models are presented in a close-loop structure.

AB modelling simulates the operation and collocations between autonomous agents. While each agent has its own individual perception and incomplete information of an end-to-end process, they are able to communicate and share information with other agents. The behavior of an agent is defined by its internal state, which is a cognitive structure that determines what action the agent takes at time t, give its perception of the environment [12].

3 Hybrid Simulation

Clearly, the above-mentioned three basic simulation paradigms are different in terms of level of abstraction [9], as they capture and imitate the dynamics of the system at either operation level or context level [13].

From 1997 papers on comparing or integrating SD and AB modelling have surfaced, commencing with Kim and Juhn [14] who compared the main features of AB and SD, focusing on different perspectives on the population of homogeneous actors such as producers, transporters and consumers. In [15] Scholl called for the unification of SD and AB, since they both depart from similar assumptions. In particular, they are unique in modelling nonlinear complex systems (e.g. urban planning systems), assume that micro-structures of a system are responsible for its behavior, and aim at discovering leverage points in complex systems. AB modelers seek them in rules and agents, while SD modelers do so in the feedback loops.

The most common two approaches of unifying SD and AB are either using SD to model the global environment while having individual agents inside [14] [16], or modelling an agent's internal structure with the help of SD [17]. For example, Akkermans [16] explores the decentralized co-ordination between multiple agents in supply chain management by modelling multiple convergent supply networks with SD. Every actor in the networks captures a mental model of the performance of the actor it is interacting with. The actors' behavior is adapted based on their mental models and influenced by their past behaviors. Such combined simulation model provides the complexity of the behavior of the involved supply chain agents, and the feedback perspective that drives most of the decisions and actions of them. Also in a supply chain setting, Schieritz and Grler's approach [17] contrasts with Akkermans' choice. They model the supply chain schemata in AB terms, and agents' mental models in SD terms. The decisions made from the agents' internal structures influence the agents interactions, and based on the agents' interactions the supply chain structure is formed.

Hybrid SD-DES modelling approaches started to appear around the late 1990s and early 2000s in software industry. More recently, researchers from disciplines other than software, such as manufacturing and construction, also started working on hybrid SD-DES simulation. Alvanchi et al. [18] concluded two main categories of hybrid SD-EDS simulation, which are (1) works focused on improving hybrid architecture development, and (2) works proposing improvements for system modelling by integrating previously neglected hybrid interactions to increase modelling accuracy.

There are three basic structure types for hybrid SD-DES modelling [18], namely SD dominant, DES dominant and parallel SD-DES structures. In SD dominant hybrid modelling, the top-level feedback interactions are modeled in SD, and DES is used to simulate the internal sequential interactions of several effective variables in the SD model. The direction of interactions is from the DES part to the SD part. In DES dominant hybrid modelling, the top-level system structure is modeled with DES, and the SD is applied to model the feedback interactions inside several variables of the DES model. Contrary to the previous type, the direction of interactions here is from the SD part to the DES part. Parallel hybrid SD-DES modelling is preferred when there are mutual effects between sequentially inter-acting components and the components interacting through feedback loops.

4 Towards a Hybrid Simulation Approach for Service Networks

We heavily rely on simulation to run and analyze scenario that consider various service network configurations and/or resource allocation in a virtual environment. Such analysis typically cannot be conducted in the real-world settings, given critical constraints imposed by the environment (e.g. geographical and organizational barriers) and our inability to travel through time (e.g. assess the business performance for 3-quarter period in advance). These arguments are especially for service networks that have expanded business reach and range with global partner collaborations while service provision and management is decentralized. This makes the end-to-end processes that live within them much more dynamic and complex than ever before.

We strongly believe that using a hybrid simulation modelling approach would enable us to predict, analyze and visualize the impact of changes in service networks over time, and trace back to the root-cause of performance anomalies and errors. Unfortunately however, existing hybrid simulation approaches for business processes typically assume that the environment in which those processes live are rather stable and limited in terms of the nature and number of actors and interactions. For instance in software industry, the software development projects have a sequential nature and limited number of interactions between context and operation variables [19].

Figure 1 graphically depicts our hybrid simulation model that comprises: network, partner and resource dimension.

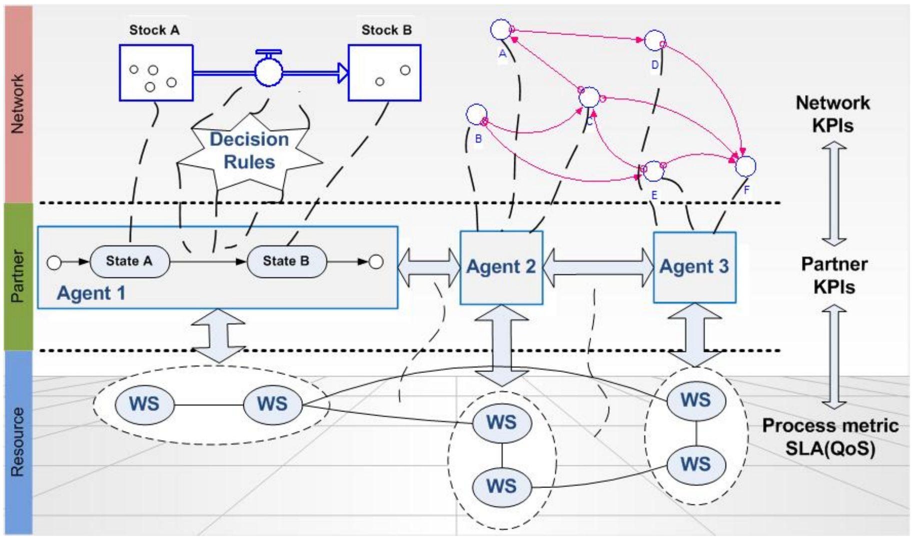


Fig. 1. Towards a hybrid simulation approach for service networks

The bottom layer of Figure 1 makes up the resource layer of service networks, constituting two types of processes, viz. software service-enabled process orchestrations that are under the control of single network actors (cf. the white spheres), and end-to-end service enabled process choreographies (cf. arrows connecting the spheres).

Each software service-enabled process orchestration (SEPO) defines the logical sequencing and timing of software service invocations, e.g. Web Service (WS) orchestration, from a local/single system point of view. Their performance is typically expressed with Quality of Services (QoSs) metrics, such as web service response time, web service availability, security, and, reliability. SEPOs are scripted into choreographed service-enabled processes (CSEPs) that support end-to-end process interactions between network partners in a service network. CSEPs are governed by Service Level Agreements (SLAs) that meticulously stipulate the QoS that may be expected from each network partner, as well as penalties in case of non-conformance. Analysis and evaluation of end-to-end performance in service networks thus implies simulating aggregated (or global) SLAs in order to find the set of SLAs that leads to the desired performance, e.g., in terms of lead time or response time. We will rely on discrete event simulation to simulate SLA performance of SEPOs and CSEP at this level of our framework, since it has been a proven its effectiveness in evaluating QoS of software applications [20].

The middle layer in Figure 1 is called the partner layer, and models the SEPOs and CSEPs from the perspective of service network partners. We rely on Agent-based modelling for this purpose. Each agent has its own perception of itself participating in CSEPs and collaborating with other involved agents. Part of the agent's behavior is modeled as state automata, for instance for Agent 1, it shows the changes of its state from State A to State B. The bidirectional arrows between Agent 1 and Agent 2, and between Agent 2 and Agent 3 denote the interactions among them.

In particular, this level aggregates the QoS of partner SEPOs in the context of all CSEPs in which they participate, and subsequently maps aggregated QoS over a span of time (mostly some months) to partner KPIs. For example, Agent 1 in Figure 1 aggregated the QoS of the Web Services at the resource layer such as response times to partner KPIs such as average throughput. In addition, the interactions among the agents reflect the aggregated performance of all CSEPs, and are also influenced by the global SLAs in resource layer.

The top layer models and evaluates performance of the service network at large. This thus means not only aggregating the performance of all CSEPs over all participating partners, but also the KPIs of all network partners, and subsequently tuning performance at the resource and partner level so that the optimal performance is reached at the service network level. The service network layer is modelled, simulated and visualized with system dynamics. By running the simulation, we aim to quantify, predict and visualize network-level KPIs, and analyze the impact of changes on the network performance over time by posing what-if scenario. In jargon of system dynamics, this involves tweaking corresponding stocks, flows and variables.

5 Exploratory Case Study

The hybrid simulation model that has been introduced in section 4 will now be further illustrated and explored. In this extended abstract we restrict ourselves to giving a high-level overview of the case study.

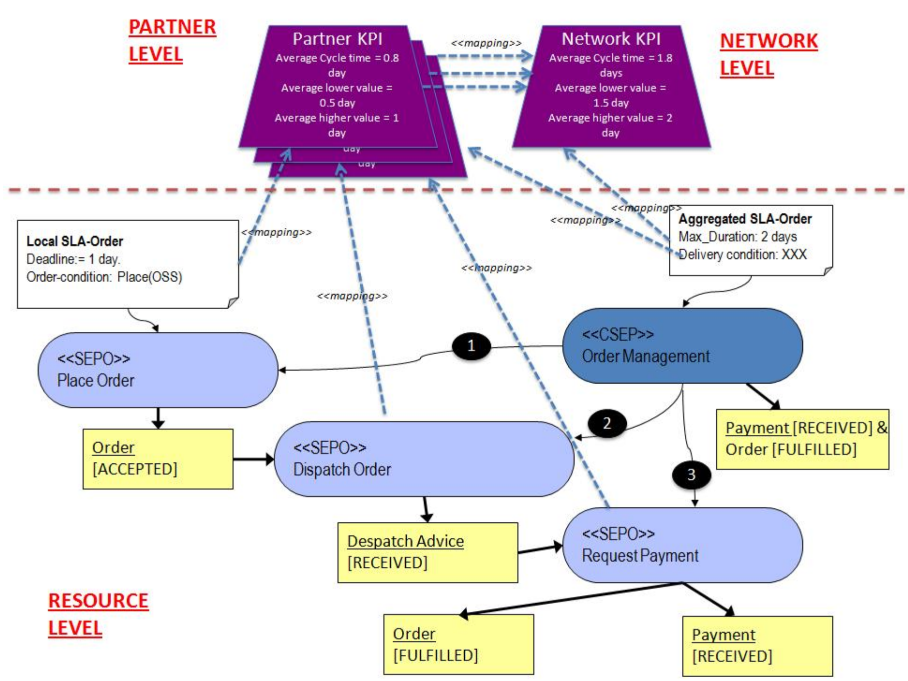


Fig. 2. Exploratory case study

This case study models a service network comprised of three network partners, each of which provisions one SEPO, viz. Place Order, Dispatch Order and Request Payment (see light blue rounded boxes). Collectively, these three SEPOs make up the CSEP Order Management (see dark blue rounded box). Note that the performance of SEPOs is rendered with local SLAs (see for example the local SLA Order that is associated to the Place Order SEPO), whilst the global performance is reflected in the aggregated SLA Order that is associated with the Order Management CSEP. Now, in our hybrid simulation model, the local SLAs attached to the SEPOs are aggregated, and subsequently mapped to Partner KPIs (e.g., the deadline stipulated in the SLA Place Order is mapped to the average cycle time KPI of purchase orders). The aggregated SLAs associated with CSEP are linked with KPIs of partner interactions. Next, the KPIs of both partners and partner interactions, together with aggregated SLAs, are mapped into network KPIs (see stereotyped dotted blue arrows). For example, the optimal average cycle time at the service network level reflects the global SLA Order Management under the constraint of optimization of the partner and partner interaction KPIs.

The black circles (labelled 1,2,3) render three events to be fed into discrete event simulation model at the resource level, whilst the yellow boxes reflect the state (changes) of the three agents (each of which realizes a SEPO), which are rendered as stocks in the SD service network model. The local and global SLAs are rendered as decision rules at the partner level, and constraint information at the network level.

We will present this exploratory case with more detailed simulation models in the final paper.

References

1. Paulson, L.D.: Services science: A new field for today's economy. Computer **39** (2006) 18–21
2. van den Heuvel, W.J.: Changing the face of the global digital economy. Inaugural Address (November 2009)
3. Papazoglou, M., Ribbers, P.: e-Business: Organizational and Technical Foundation. John Wiley (2007)
4. Greasley, A.: Using process mapping and business process simulation to support a process-based approach to change in a public sector organisation. Technovation **26**(1) (January 2006) 95–103
5. Tan, Y., Takakuwa, S.: Predicting the impact on business performance of enhanced information system using business process simulation. Proceedings of the 2007 Winter Simulation Conference (2007) 2203–2211
6. Hlupic, V., Vreede, G.J.D., Orsoni, A.: Modelling and simulation techniques for business process analysis and re-engineering. International Journal of Simulation **7**(4) (2006) 1–8
7. Gladwin, B., Tumay, K.: Modeling business process with simulation tools. In: Proceedings of the 1994 Winter Simulation Conference. Volume 1994. (1994) 114–121
8. Seila, A.F.: Introduction to simulation. In: Proceedings of the 1995 Winter Simulation Conference. (1995) 7–15
9. Borshchev, A., Filippov, A.: From system dynamics and discrete event to practical agent based modeling : Reasons , techniques , tools. The 22nd International Conference of the System Dynamics Society (2004)
10. Forrester, J.W.: Industrial Dynamics. Pegasus Communications (1961)
11. Coyle, R.: Representing discrete events in system dynamics models: A theoretical application to modelling coal production. The Journal of the Operational Research Society **36**(4) (April 1985) 307
12. Anderson, P.: Complexity theory and organization science. Organization Science **10** (1999) 219–232
13. Lee, S., Han, S., Pena-Mora, F.: Hybrid system dynamics and discrete event simulation for construction management. In: ASCE International Workshop on Computing in Civil engineering, Pittsburgh, PA. (2007)
14. Kim, D.h., Juhn, J.h.: System dynamics as a modeling platform for multi-agent systems. In: The 15th International Conference of The System Dynamics Society. (1997) 1–7

15. Scholl, H.: Agent based and system dynamics modeling: A call for cross study and joint research. In: HICSS '01: Proceedings of the 34th Annual Hawaii International Conference on System Sciences (HICSS-34)-Volume 3, Washington, DC, USA, IEEE Computer Society (2001)
16. Akkermans, H.: Emergent supply networks: System dynamics simulation of adaptive supply agents. Hawaii International Conference on System Sciences **3** (2001)
17. Schieritz, N., Grossler, A.: Emergent structures in supply chains - a study integrating agent-based and system dynamics modeling. In: Proceedings of the 36th Hawaii International Conference on System Sciences, Ieee (2003) 94–102
18. Alvanchi, A., Lee, S., AbouRizk, S.: Modeling framework and architecture of hybrid system dynamics and discrete event simulation for construction. Computer-Aided Civil and Infrastructure Engineering **00** (February 2010) 1–15
19. Choi, K., Bae, D.h., Kim, T.: An approach to a hybrid software process simulation using the devs formalism. Software process improvement and practice **11**(June) (2006) 373–383
20. Jamoussi, Y., Driss, M., Jezequel, J.M., Ghezala, H.H.B.: Qos assurance for service-based applications using discrete-event simulation. International Journal of Computer Science Issues **7** (2010) 1–11

Application of Social Network Analysis to Service Networks Performance Analytics

Noel Carroll

Lero - the Irish Software Engineering Research Centre
Department of Computer Science & Information Systems
University of Limerick
Ireland
Noel.carroll@lero.ie

1. Introduction

Nowadays, organisations are becoming increasingly interested in understanding the operations of service networks as a means to adapt to the ever-changing business environment. In order to deliver effective services, providers are being advised to '*innovate'* their service delivery systems. Innovation in this context often refers to technology, technique or restructuring service improvements. However, the difficulty is that in the modern organisation, service delivery is dispersed across complex service eco-systems. Thus, there are greater pressures on organisational service systems to deliver higher quality and more efficient service as management continue to invest in information systems (IS) or business applications. Management must attempt to develop a greater understanding of service processes to identify where improvements may be made by employing business process management (BPM). The network approach ultimately makes service innovations and service (re)configuration more difficult to implement, monitor, and report on service performance. We are often led to believe that we live in a 'global service network', surrounded by networks of power, influence, and relationships (for example, Law, 1999). We can adapt Mitchell's (1969, p.2) description of a network as *a specific set of linkages among a defined set of actors, with the additional property that the characteristics of these linkages as a whole may be used to interpret the service behaviour of these actors involved*. The interaction patterns exhibited within service environments (physical and virtual) are of critical importance to performance analytics. In this section, we discuss how social network analysis (SNA) allows us to explore how we may analyse, design, and/or reconfigure service networks, across distributed communication and collaboration structures (Cross and Parker, 2004). In addition, we adopt actor network theory (ANT) as one of core theories upon which we can examine service relations and their effects on service performance between service actors (for example, people, organisations, and IS). The network topology which is exhibited as a result of service interactions are often concerned with '*spatiality*' and their measurable and scalable attributes which emerge over time with particular coordinates to retain service integrity provide us with insight on service dynamics and resulting performance. This section explores the concept of a 'service network' with particular attention placed on performance analytics and identifies the need to incorporate service performance analytics within BPM to enhance the manageability of service networks. Often, an important decision requires better knowledge of both tangible and intangible factors. If managers fail to report service performance, it is increasingly likely that resources will be misallocated, innovative ideas will be rejected, money is wasted, quality of service is jeopardised, and service reputation is at risk. For example, the risk of failure with an IS to support service delivery, the value of information exchanged between service actors, the strength of a service and its relational ties, strategic alignment, of which is economically justifiable, within a service eco-system. This is largely the result of lack of measurement on service performance analytics to inform decision-making tasks within the service environment.

2. *The Service Environment*

The service environment is comprised of complex business interactions often influenced by the affordance of technology. The growth in '*service science*' as a discipline has underscored the need to investigate the contributory value of business processes and its influence on how a service system affects the delivery of organisational performance. Within organisational and technological management theory, understanding and measuring value (i.e. *application of competences*) of service networks is considered one of the key problems which prevent the sustainability of organisational growth. Value may be referred to as "*the adaptability and survivability of the beneficiary system*" (Vargo et al., 2008; p. 148) although we focus on value through performance analytics. Understanding the value of service system infrastructure after investing often proves to be one of the greatest challenges (Weill et al., 2002). Therefore, assessing the business value of service processes is of critical importance. Service science explores the value *co-creation* of interactions between service systems (for example, Spohrer and Magilo, 2008; Vargo et al., 2008). Modern service systems have become very complex while technology continues to contribute towards organisational "*flattening*" (Friedman, 2006) which adds to the complexity and evolvement of service system (Chesbrough and Spohrer, 2006). The wealth of information available on people and their roles, technology and processes, organisations and activity or performance has never been greater, nor has the prospect to (re)configure them into service relationships to examine, create, and manage service value. Technological advances continue to act as a driving force for '*making new patterns and a new elevated level of value creation possible'* (Normann, 2001; p. 8). In addition, Normann (1991), provides a framework to examine the driving forces behind innovation in service management systems (table 1) of which we adapt for a service network:

	External driving force		
Internal basis for service management innovation system	**Fossilised or regulated institutional context**	**New values, lifestyles and problems**	**Need for greater efficiency (core or non-core activities)**
Social innovation • Client participation • Roles sets • New linkages • New sources of human energy	Traditional organisation	Service network performance analytics	Web 3.0
Technological innovation	Service network	Business process management	• Cloud computing • Service computing
Network effects	Service eco-systems	Service modelling techniques, e.g. social network analysis	Mobile technology
Reproduction innovation or scale advantage in management	Value co-creation systems	Service network management	• Service management • Risk Management • Performance Management • Decision support systems

Table 1 - Driving forces of service management systems (adapted from Normann, 1991)

As service networks continue to grow, understanding the dynamic exchange of resources which creates "service value", determined through specific relationships and interactivity between service systems and specific business processes is of significant importance. This is often overlooked as service networks are often perceived to be immeasurable. According to Hubbard (2007; p. 19), there are three different aspects why people believe something cannot be measured:

1. *Concept of measurement:* the definition of measurement itself is widely misunderstood. If one understands what it actually means, a lot more things become measurable.
2. *Object of measurement:* the thing being measured is not well defined. Sloppy and ambiguous language gets in the way of measurement.
3. *Methods of measurement:* many procedures of empirical observation are not well known if people become familiar with some of the basic methods, it would become apparent that many things thought to be immeasurable, may be measured.

In addition, Hubbard (2007), lists three main reasons why measurement may be considered inappropriate, namely; economic (too expensive), usefulness and meaningfulness, and ethical objections. Within a service system, measurement of performance, i.e. performance analytics, plays a fundamental role to inform management of quantify activities and reduce uncertainty by mapping business processes and their influence on performance within the service environment. The 'uncertainty reduction' is critical in service environments as it also has greater 'value' in reducing risks in decision-making tasks. Consequently, this has sought the establishment of the discipline of service science, which is briefly discussed in the next section.

3. Defining Service Science

In 2002, Professor Henry Chesbrough of Berkeley's IBM Almaden Research Centre identified the need to research services from a social engineering perspective, and coined the concept of "*service science*". The "*science*" within services has emerged from the amalgamation of engineering and management disciplines. There is no clear definition of what constitutes as service science, as this changes when applied to various research fields or industrial sectors. However, Spohrer et al., (2007) offer a definition of 'science' as, "*the agreed upon methods and standards of rigor used by a community to develop a body of knowledge that accounts for observable classes of phenomenon in the world with conceptual frameworks, theories, models, and laws, that can be both empirically tested and applied to benefit society*" (p. 1). As service science undergoes numerous theoretical developments and evolves across several research fields (for example, management, supply chain, computing, human resource management, contracting economics, operations, marketing, engineering, innovation, and social science) it is premature to expect that we can pin down service science precise meaning. However, Spohrer et al., (2007) identifies four key observations about these disciplines:

1. The disciplines are ***heavily resource dependent*** (people, information systems, interaction of organisations). There is a need to understand the efficient application and configuration of resources to create value.
2. Disciplines often tend to ***integrate or coordinate resources*** to meet an organisational goal.
3. ***Measuring performance*** is very important and criteria to measure may vary according to each discipline.
4. Many of these disciplines ***incorporate the word "service"***, e.g. service engineering, service management, service innovation, and service supply chain. This is due to the transformation in society with the view of value in goods and value in service exchanges.

Service science seeks to develop a knowledge-base from several disciplines including innovation, operations and performance, business process management, and technology. This is increasingly more obvious, as we develop the concept of the '*service network*' with a view to understand performance analytics. Therefore defining service science is largely influenced by the context in which it is applied. Broadly speaking, services science may be described as a discipline which sets out to develop methods to extend the availability and accessibility of business processes across service systems while developing methods to evaluate service performance through a scientific lens. It is also concerned with improving manager's ability to predict risk, estimate their effects, and reduce uncertainty through modelling the value-exchange which results from provider and client interaction during intellectual, behavioural, economic, and/or social activities. Services are normally characterised by a number of key factors, including:

1. Intangible
2. Differentiation or 'uniqueness'

3. Non-transfer of ownership rights
4. Difficult to access before initiating a service agreement, and
5. Production and consumption occur simultaneously.

The notion that within a service, it is difficult to access its contribution towards a business's performance must be addressed within service science. The service sector has come to the forefront of the developed economies to add increased value and accessibility within several sectors (private and public). In many cases services have ignited a change within international industrial structures and indeed within business. For example, Abe (2005), suggests that if compared to the manufacturing industry, productivity in the service sector is low and requires vast improvements which affect the process of accessing service network value. We have witnessed several trends in innovation across service industries. These are summarised as follows (Normann, 1991):

Transfer of manpower and product	→	Transfer of: • Customer-orientated systems • Knowledge • Management
Innovation in 'products' and 'service packages'	→	Innovation in delivery systems and distribution: • Reproduction ('McDonaldisation') • Packaging of knowledge
The dominating 'product'	→	The active, dominating customer (tools for self-help)
Technical innovation	→	Social innovation and 'hi-tech'-'hi-touch' (organising behaviour and social interaction).
Network innovation	→	Combines the transfer of skills, competence, technology, and innovation to deliver a service.

Table 2 Trends in innovation of service industries (adapted from Normann, 1991)

Although table 2 above highlights some of the emerging trends across the service sector with particular attention towards 'network innovation', the literature indicates that service science practitioners have fragmented understandings of what constitutes as service science, how are services managed, and how can managers exploit service capabilities. This is often based on practitioners experience and an attempt to scientifically document their experiences, such as assessing risk, or measuring the level of productivity. Technology is often referred to as the backbone to many of the service providers. In addition, the Internet has fuelled the expansion of a plethora of services and service networks, for example, service clouds. The number of services and variety of services continue to increase and so too will their complex environments. In fact, services are now the dominant contributor to the developed economies. As a result, the business landscape has significantly changed, i.e. a shift from a goods-dominant logic towards a service-dominant logic (Normann, 2001; Vargo et al., 2008). It is evident that a scientific understanding of modern services is undeveloped and may even be described as an unexplored topic which sought the introduction of "*service science*". Service science is an attempt to "*study the application of the resources of one or more systems for the benefit of another system in economic exchange*" (Spohrer et al., 2007; p. 2). One of the fundamental objectives of service science is to understand the mechanics of service networks and define how and why they generate value. One of the core problems in understanding the dynamics and complexity of service science: "*powerful dynamics are in play around the world when it comes to applying resources effectively to solve problems and create value*" (Spohrer et al., 2007; p. 10). Value (for example, economic, social, and interaction exchange) is the core of service sustainability. Across large service networks, reorganising, consulting, and exchanging on business processes is becoming increasingly more important within service science. Therefore, understanding the complexity of network structures, process patterns, and methods to improve network performance is critical to the success of service eco-systems, for both the service provider and client.

Service science extends business functionality and attempts to optimally map business performance in vertical and horizontal business structures. Spohrer et al., (2007) identify five main criteria within a service (summarised in table 3 below):

Criteria	Explanation
Resource	Must begin to understand the value of resources and how does service interaction behaviour influence value, i.e. what is gained and what is lost during interactions?
Entity	The entity is the service system (or an actor; person, organisation, information and technology or the configuration of all four). One of the resources must be the operant resource. Informal interactions have not been recognised or measured within service science to anticipate problems that may arise in value co-creation value interactions. Much focus is on service design, propose, agree, and realise value within a service system. It must dynamically adapt the value proposition and change over time.
Service	One or more entities must perform the application of competencies and one or more entities must receive the benefit. Must understand what resources are transmitted over certain time and space which interact and co-create value. All entities judge value from a unique frame-of-reference and context. What happens when things go wrong?
Interaction	Interactions generates an outcome. Value is determines whether it has been added or destroyed through unique frames of reference. Desired outcome is a win-win co-creation value. There are four main outcomes from interaction: 1. Win-win value co-creation 2. Lose-lose value co-destruction 3. One entity judges that value is created 4. One entity judges that value is destroyed Assessment of value depends on the frame of reference of the service system which may judge on historical performance as well as expectations (goals), quality, satisfaction of customer experience, improved value, and agility. Designing value propositions and realising the potential in interaction is what service systems must embrace in order to exist. The design of a successful value proposition requires knowledge of: 1. The provider's capabilities and needs 2. The customers' capabilities and needs 3. The competitions capabilities and needs 4. What authority (legal system) will allow Failing to understand any one of these factors can destroy value opportunities within the system. The ISPAR Model (Interact-Serve-Propose-Agree-Realise) allows us to view the world as populations of interacting systems of different types (people, business, etc). Interaction patterns can also reveal the value of participation.
Success criteria	An important question for a service system is to anticipate what constitutes success? Success requires both relevance and rigor. Calling for a rigorous theory of service systems to explore how entities interact, how they persist, what value they co-create will require integrating theories. Literature indicates that there is a significant opportunity in integrative system thinking in service science. We explore this in the context of key performance indicators (KPIs)

Table 3 - Main Criteria within a Service (adapted from Spohrer et al., 2007)

As identified above, service science plays a central role in supporting our quest to learn how service network and service exchange influence service performance. Interestingly, the evolution of business process management over the last decade provides an overlap on the need to gain a greater insight on business processes.

4. Exploring and Refining Business Processes

Although the service sector is considered the primary contributor to the global economy, there are minimal research efforts to introduce methods which examine service network performance analytics. This is particularly true within the field of information systems (IS). In addition, service quality management efforts have been limited within business process management (BPM) and service science, and one of the reoccurring arguments for this is that "*service processes are unseen,* *intangible, and even immeasurable*". As a result, performance analytics is often overlooked and this mindset towards services allows managers to become rather presumptuous especially within the service eco-systems. This section briefly examines what is implied by a business process, and in doing so, this study sets out to fragment the business process into measurable factors which impact on service performance (which is discussed later). Hubbard (2007), describes this process as a 'clarification chain' which is '*a series of short connections that should bring us from thinking of something as an intangible to thinking of it as tangible*' (p. 26):

1. If it matters at all, it is detectable/observable
2. If it is detectable, it is detected as an amount (or range of possible amounts)
3. If it can be detected as a range of possible amounts, it can be measured.

The overall objective of evaluating the implementation of a business process within a service network is an attempt to improve business or service functionality. Thus, we must understand the various dimensions of the business process (for example, structural, behavioural, compositional, and functional) and its contribution towards service performance. The term, 'business process', has been well documented across literature in the hope to shape and reshape a more universally accepted meaning of the term. For example, Davenport (1993), defines a business process as *"...a structured, measured set of activities designed to produce a specific output for a particular customer of market*" (p.5). In addition, Hammer and Champy (1993) defines a business process as a: *"…collection of activities that takes one or more kinds of input and creates an output that is of value to the customer*" (p.35). In more recent years, Smith and Fingar (2003) define a business process as, "…*the complete, end-to-end, dynamically coordinated set of collaborative and transactional activities that deliver value to customers*". Smith and Fingar also dissect their definition, and extract the key characteristics of business processes. They specify eight characteristics of business process as follows:

1. ***Large and complex:*** involving the end-to-end flow of materials, information and business commitments.
2. ***Dynamic:*** responding to demands from customers and to changing market conditions.
3. ***Widely distributed and customised across boundaries:*** within and between organisations, often spanning multiple applications on disparate technology platforms.
4. ***Long-running:*** a single instance of a process such as "order to cash" or "develop product" may run for months or even years.
5. ***Automated:*** at least in part. Routine or mundane activities are performed by computers whenever possible, for the sake of speed and reliability.
6. ***Both "business" and "technical" in nature:*** IT processes are a subset of business processes and provide support to larger processes involving both people and machines.
7. ***Dependent on and supportive of the intelligence and judgment of humans:*** the tasks that are too unstructured for a computer or require personal interaction with customers are performed by people. The information flowing through the automated systems can support people in solving problems and creating strategies to take advantage of market opportunities.
8. ***Difficult to make visible***: these processes are often undocumented and embedded in the organisation. Even if they are documented the definition is maintained independently of the systems that support them.

While this study explores business processes in a service network from a managerial perspective, the last characteristic is an interesting flaw within business process management ('*difficult to make visible'*). If we can model and understand the behaviour of business processes, surely we can offer a method to management to visualise the business processes behaviour and what influence (enables or inhibits) service process performance. We can also approach this, as described by Latour (1999), as concentrating "*on what is not directly visible in the situation but has made the situation what it is*" (p. 17). After all, Papazoglou, defines a business process as "*a set of logically related tasks performed to achieve a well defined business outcome*" (Papazoglou, 2003; p. 49). In addition, Papazoglou explains that a business process is designed to achieve a well-defined business outcome that determines the 'results to be achieved, the context of the activities, the relationships between the activities, and the interactions' with other processes and resources (Papazoglou, 2007). Therefore, the behaviour exhibited within BPM can provide us with a critical insight as to what influences service performance. Understanding this, relates back to how Curtis et al., (1992) once used the term 'business process reengineering', and defines it as '*the redesign of an organisation's business processes to make them more efficient*'. This is necessary considering the evolution of the "business transaction" to enrich the functional capabilities with the advent of BPM and Service Oriented Computing (SOC) which is a computing paradigm that utilises services as fundamental elements to support, rapid, low-cost development of distributed applications in heterogeneous environment (Papazoglou et al., 2009). The SOC paradigms gives rise to the Service Based Application (SBA) approach which is composed of distributed services in service networks. The rising of SBAs fosters new complexity relating to transactions and consequently, service eco-systems. SBAs transcend the organisational boundary, where services interact with multiple participants to accomplish transactions for end-to-end processes and these interactions underlie the transactional properties of services. In other words, transaction properties are the main drivers of the interactions between (or among) services or participants in networks of services. Thus, any erroneous or faulty transaction configuration (or modelling) underpinning the composition of SBAs may exacerbate the risk of degrading the overall performance of entire service networks no matter how well the other functionalities were configured. Additionally, the incomplete transaction configuration is similar to the traditional transactional approach because it does not add any advantage on the top of traditional approaches. The incompleteness refers missing essential business elements such as Quality of Service (QoS), KPI, and Business Protocol in transaction approach that supports transactionality of SBAs, all of which are determines by the execution of the 'business process'.

However, this notion of business process performance analytics in not entirely new, for example, back in 1993, Hammer and Champy advises us to "*forget everything you have known about how business should work – most of it is wrong*". Interestingly, the literature to date up to 2010 coincides that this is largely true as we are beginning to realise that we remain uncertain as to the contributory value of service network infrastructure and processes within and across organisations (Wellman et al., 1996; Huffman, 1997; Cross and Parker, 2004; Huysman and Wulf, 2006; Lundqvist, 2007; Wang et al., 2007; Van Heck and Vervest, 2007; Sykes et al., 2009; Hassan, 2009). In fact, Normann (2001), challenges Porters goods-dominant 'value chain' and suggests that this is no longer relevant within the service-dominant world. Within the service-dominant environment, organisations are under increased pressure to adapt their business processes at a much faster pace than they have ever experienced before (Hubbard, 2007; Pedrinaci et al., 2008). Time and quality are two key factors in the deliverance of a service. Managers must be proactive and decisive to embrace change and meet consumer needs (Weill et al., 2002). Thus, strategic management of service technology is essential to reduce the probability of failure, risk, and damaging service reputation (Weill et al., 2002; Brem and Voigt, 2007) as well as the coordination of people within the service system. We will refer to these as 'actors' which are comprised of, for example, organisations, people, IS, and software, which is further explored in this document. According to Weill et al., (2002), investing in IT infrastructure is a major challenge for senior managers as many of them are often unprepared to make such decisions. In addition, understanding the value or influence in service performance of this infrastructure after huge investment often proves to be an even greater challenge (Weill et al., 2002; Carr, 2004). Assessing the value of the IT-enabled business processes is of critical importance as it reveals how an organisation is positioned within a much larger eco-service network. Managing business processes (for example, discovering, monitoring, changing or redesigning) are essential activities across distributed business applications. According to Brem and Voigt (2007), many companies fail because they cannot manage these fundamental factors successfully.

A common objective of measurement, as described by Hubbard (2007; p. 27), is that "*the problem is unique and has never been measured before, and there simply is no method that would ever reveal its value*". Gathering data on the health of service performance across a large service network is of critical importance. Organisations must attempt to shape and exploit service data, information and knowledge if they want to strengthen their competitive position or form strategic service network alliance. One of the major problems, as outlined by Becker (2007), is that managers are faced with a serious issue of how to manage "*a completely invisible asset*". Another problem highlighted by Cross and Parker (2004), is that in the past managers have ignored the "*dynamic characteristics of networks* *and the ways that dynamic qualities of networks affect organisations' flexibility and change*" (pp. 133). This has unavoidably led to organisations failing to capture and understanding the 'health' of their service performance, positioning, structure and infrastructural workflows within business processes. Many technologies and business models are incapable of meeting dynamic requirements of today's business world, and appear to employ a continuous 'catch-up' approach, forcing organisations to compensate for technological inadequacies (Orlikowski, 1992; Doherty et al., 2003). The modern business model should present methods to calculate the value of organisational networks (Normann, 2001). Another problem appears to include that although the business infrastructure (delivering a service) has changed over the last few decades (service-dominant), the fundamental logic ("back to basics") of running a business has remained quiet static (goods-dominant). Morabito et al., (1999) advocates that it is now time to move from the 19th century organisational model towards a 21st century model. The organisational model has never drastically changed, although IS development continues to accelerate, influence, and alter organisational phenomena, in what is now a service-dominant environment. The literature indicates that we must begin to unwrap the underlying principles in dynamic business processes to learn how processes operate and become more efficient (for example, see, Agrawal et al., 1998; zur Mühlen and Rosemann, 2000; Verbeek et al., 2001; Weijters and van der Aalst, 2002; Weijters and van der Aalst, 2003; van der Aalst, 2004; van der Aalst, 2007; van der Aalst et al., 2004; van der Aalst and Hee, 2004, Reijers et al. 2009). In addition, Camarinha-Matos and Afsarmanesh (2007), draw our attention to the need to clearly understand related reference models before we attempt to capture organisational complexity through a new reference model. This is especially true within the service network.

5. The Service Network

This section explores the concept of the '*service network*'. To gain a better understanding of the service network, we must first explore what is meant by a service. Today's customer offerings, whether packed as physical 'products' or offered as 'services', 'software', 'portals', 'relationships', or in other shapes, all embedded in a 'brand' concept, tend to be designed to evoke and stimulate emotional, intellectual, and physical actions within the customer (Normann, 2001; p.119). This is a generally accepted explanation of how services generate value within service literature. Within the IS discipline however, little research exists towards the exploration into the influence of technology in service design, delivery, and overall performance, i.e. the implications of relational structures on service performance, which suggest the need to revisit the modern concept of the 'service'. For example, back in 1977, Hill defines a service as: "*a change in the condition of a person, or a good belonging to some economic entity, brought about as a result the activity of some other economic entity, with the approval of the first person or economic entity*" (Hill, 1977). Economics typically attributes 'transactional value' or market value to assets, but when applied to a service, it becomes more difficult to assign an individual economic actor (Normann, 2001). A market handles these complexities and establishes the market value which is determined by the buyer and seller, mainly through interaction and the exchange of resources and/or competencies. What is of interest here is the transactional value of a service network. Transactional value may refer to satisfying transactional properties including performance constraints (e.g., key performance indicators), quality constraints (e.g., 'Quality of Service' guarantees), action constraints (e.g., 'notification'), and consistency (e.g., consistency of interaction states). This is critical within a service environment, considering a service involves multiple parties (at least two) and a service may be viewed as the networked behaviour to offer a specific capability from one party to another through a predefined protocol or service compositions (for example, a service level agreement). Defined by Jobber (1998), a service can be defined as "*any act or performance that one party can offer to another that is essentially intangible and does not result in the ownership of anything. Its production may or may not be tied to a physical product*". This suggests that the emphasis has shifted from the change in condition to the performance of the actor. In fact, a physical product may be referred to as a representation, or an accumulation of past knowledge and activities (Normann, 2001; p. 116). Here Normann shifts the focus to the relational value of delivering a service. In addition, Fitzsimmons and Fitzsimmons (2004), offer a definition of a service as a "*...time-perishable, intangible experiences performed for a customer acting in the role of a co-producer*." Thus, service interaction plays a significant role in the evolution of service networks and presents us with greater insight on service performance. Services are a fundamental factor in every organisation, for example, telecommunication, health care, education, retail, and finance, thereby extending the value of the 'business transaction'. In this sense, business transactions carry a code or a pattern which embodies specific performance analytic metric matches and allows us to monitor the dynamic behaviour. Figure 1 illustrates the dramatic shift in business logic from an assets dominant perspective to a reconfiguration of value-creating system. This is adapted from Normann (2001) as figure 1 illustrates that significant shift towards a new strategic logic of the 'service networks'. Services extend business processes and business functionality within (cross-departmental) and outside (cross-organisational) of an organisational service network. The behaviour in which it exhibits (through the mapping and visualisation of actor exchange) indicates the value of business processes and the emergence of the service network begins. The emphasis here is on the relational structure which exists between service processes and business transactions. Bearing in mind that a service is often referred to as "*protocols plus behaviour*" (Spohrer and Maglio, 2009), a service network may be defined here as a collection of actors (people, groups, organisations, information systems, etc) who exchange resources and competencies, governed by business protocol (including behavioural protocol) via collaborative relational structures. To emphasis the behavioural factor, Normann (2001), considers services as "*activities (including the use of hard products) that make new relationships and new configurations of elements possible*" (p. 114). Service activities include co-generated exchanges of largely intangible assets, collective coordination, orchestration, and integration of knowledge under negotiated conditions which are transacted between the service provider and client. The complexity of the service system or on-demand business architecture is often misunderstood which requires the introduction of new theoretical developments. Therefore, managers must begin to view services through a scientific lens to construct reusable and standardised modelling methods to evaluate and govern service networks. The main emphasis here is the competence to organise value creation as it extends beyond the traditional boundaries and transactions are dispersed across a web of interrelated service networks. This is largely due to the affordance of technology and the virtual organisational infrastructures (for example, cloud computing). Normann (2001) coins the paradigm "reconfiguration of value-creating systems", although we extend this to incorporate "business transactional networks" to highlight the shift of focus on the customer now placing more importance on the relational structures and business transactional properties which exist within service ecosystems. The importance of this is further highlighted in the emerging discipline of service science. However, the concept of business transactions within service science is overlooked. We identify the need to bring business transactions into a service network context (figure 1).

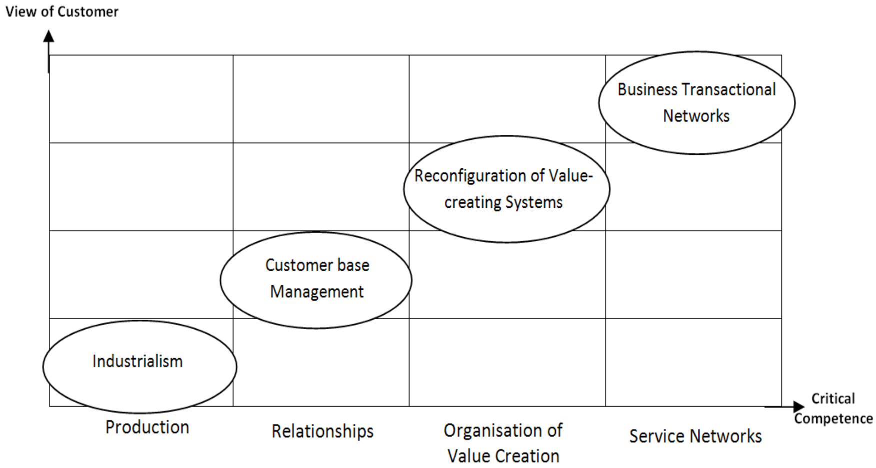


Figure 1. Evolution of Strategic Paradigms (adapted from Normann, 2001)

Our traditional understandings of the 'organisation', with solid boundaries and internally focused on operations, time, and individuality are becoming less apparent today. As competitive advantages of single organisational strategies continue to erode over recent years, organisations are experiencing greater demands to operate with increased innovation, collaboration, scalability, efficiency, agility, and virtuality (for example, Zairi, 1997; Morabito, et al., 1999; Rust and Kannan, 2002; Brynjolfsson and Hitt 2003; Afsarmanesh and Camarinha-Matos 2005; Bender-deMoll and McFarland, 2006; Friedman, 2006; Krebs, 2007; Van Oosterhout et al., 2007; Hubbard, 2007; Chen, 2007; Glenn, 2009; Hsu, 2009). Therefore, this study defines a service network as 'a complex sets of social and technical interactions which exchange resources and competencies to create economic or social value'.

Over the past few years business practices have changed dramatically for several reasons including; globalisation, world financial crisis, accessibility of a global educated and mobile workforce, technological advances ('death of distance'), and global outsourcing. Understanding how these influences have distorted our understanding of business plays a significant part on how we interpret service networks. Many of these changes require that we view business with a new mindset to understand the interactions of global and electronic infrastructure which supports service operations. Transparency within service operations is envisioned as a critical factor within service innovation (Chesbrough and Spohrer, 2006). In the next section, we briefly discuss the application of actor network theory (ANT) as a suitable theory to understand the dynamics of service networks and consequently, service network performance analytics.

6. Adopting Actor Network Theory

We live in a complex socio-technical environment, governed by the embedded interactions of several complex multi-actor systems and often result by influence of external entities, for example, groups, organisations, institutions, nations, and societies. Nowadays, centralised hierarchical organisational structures are becoming less apparent. Network-based constructs are reported to generate more 'openness' and are subject to frequent change within the organisational system structure. Such openness and agility within modern organisational structures promote flat hierarchies and more flexible structures (Friedman, 2006), which are fundamental characteristics of the modern organisational architecture (Cross and Parker, 2004). However, as organisations are beginning to move away from the traditional corporate hub of business practice towards a more diffused and distributed web of relationships and agile alliances, it is becoming increasingly more difficult to manage and monitor service systems delivery. There is a growing body of evidence which supports that actor network theory (ANT) allows us to gain a greater understanding of networks within the IS and consequently, the service science discipline. ANT is traced back in sociological theory, developed by Bruno Latour, Michel Callon and John Law in the early 1980s. ANT can provide a deeper understanding about 'how' and 'why' processes of 'technological innovation and scientific knowledge-creation' and is not concerned with the network per se, but rather the infrastructure which supports the network's evolution (Monteiro, 2000). It examines the performance of network relations and explores the influence of objects towards those relations (Law, 1999; p. 7). ANT research examines socio-technical influences and relational effects of actor (i.e. human and non-human) interaction within networks which support, for example, people, organisations, and technology. Law describes how ANT "*is a ruthless application in semiotics. It tells that entities take their form and acquire their attributes as a result of their relations with other entities*," (Law, 1999; p. 3). For example, one of the main factors explored by Law (1999), is the *translation*, which he describes as 'making two things that are not the same, equivalent', although it cannot inform you on how this links is formed (p. 8). In IS literature, this is often referred to as *integration*, especially when we are concerned with the homogeneity of systems integration within service eco-systems. Therefore, we can interpret translation as service integration, i.e., translated into more general and unified service solutions. This is an interesting notion when we examine the alignment of IT with business or service strategy when there is often the presumption of IT supporting service networks or service integration and ANT lends itself nicely to the exploration of doing so. Therefore, service actors (organisations, people, IS) may be viewed as representations of a networked effort to deliver a service, while unfolding the meaning (or value) of influential service actors. ANT may be adopted as a research method for a soft case study approach to examine the trajectories of service networks (for example, Walsham, 1997) and service actor interaction. The effects of such interactions are of significant interest when we examine service network interaction performance or outcomes. Law (1999) refers to these interactions as *relational materiality* and *performativity* which examines the "*consequence of* *the relations in which they are located*" (p. 4). Thus, ANT provides an alternative view from management literature of service management with the aim to understand how service systems and business strategies evolve and align. ANT presents a lens or a framework which provides a detailed description of the underlying mechanics and its infrastructure which support dynamic networks and the unbiased viewpoint of the network actors (Monteiro, 2000). Service actors (e.g. organisations, people, IS) may be viewed as representations of a networked effort to deliver a service, while unfolding the meaning (or value) of influential service actors. ANT suggests a scientific view of business activities is not necessarily different from many social activities performed by actors which form as networks and often linked to other networks. This approach also supports the emergence of service science. However, the core principle upon which ANT hinges is the notion of a *"heterogeneous network which facilitates different but inseparable socio-technical elements"* (Monteiro, 2000).

ANT is concerned with a bottom-up concept of alignment and strategy formation while alignment is more concerned with a top-down view on planning and decision-making processes (Monteiro, 2000). Therefore ANT provides a theoretical platform upon which we can begin to analyse the implications of service relational structures on performance analytics to establish clearer of facts, effects, beliefs or technological solutions within service networks and learn how IT enables and inhibits service performance. Understanding the value of service network relationships, especially from a service perspective can prove to be extremely beneficial. In this sense, value may be referred to as "the adaptability and survivability of the beneficiary system" (Vargo et al., 2008; p.148) by creating "opportunities for reinvestment and cross-subsidisation of activities that may potentially benefit people not involved in the original transaction" (Auerswald, 2009; p.53). A major consequence of ignoring service analytics is that managers cannot determine the value of the overall service eco-system or *"…capture the adaptive and evolutionary characteristics of a value network* … [and] *the nesting of supply chains with larger and more encompassing value networks*" (Lusch et al., 2010). Gathering information on customer interaction with a service provider supports managers with rich insights as to how a service network is performing to meet customer needs and how service infrastructure supports service demands. This approach is necessary as we explore key performance indicators (KPI) strategies.

ANT provides an analytical framework and explores the mechanics of network evolution, for example, power: the formation, stabilisation, and reproduction of interactions, the construction and maintenance of network structures, and the establishment of control. Power is viewed as being generated in a relational and distributed. Within ANT, the process of translation is interesting regarding its application to service level agreements (SLA), considering it is the process of establishing identities and the conditions of interaction, which characterise their representations. In this sense, translation may be described as a practice (i.e. making equivalent; service integration) and an outcome (realised effects; service reconfiguration). ANT is concerned with a bottom-up concept of alignment and strategy formation while alignment is more concerned with a top-down view on planning and decision-making processes (Monteiro, 2000). Therefore ANT provides a theoretical platform upon which we can begin to analyse the implications of service relational structures on performance analytics to establish clearer of facts, effects, beliefs or technological solutions within service networks and learn how IT enables and inhibits service performance. The importance of adopting this theoretical approach to value service networks (i.e. performance analytics) is further discussed in the next section.

7. Value of Service Networks & Challenges

Understanding the value of service network relationships, especially from a service perspective can prove to be very difficult although extremely beneficial. In this sense, value may be referred to as "*the adaptability and survivability of the beneficiary system*" (Vargo et al., 2008; p.148) by creating "*opportunities for reinvestment and cross-subsidisation of activities that may potentially benefit people not involved in the original transaction*" (Auserwald, 2009; p.53). Service value refers to the relational exchanges and examines how network interaction generates a value to satisfy a service client's need (i.e. value exchange). Thus, the value of a service network is "a spontaneously sensing and responding spatial and temporal structure of largely loosely coupled value proposing social and economic actors interacting through institutions and technology, to: (1) co-produce service offerings, (2) exchange service offerings, and (3) co-create value" (Lusch et al., 2010). Within service systems there is a large element of barter (method of collaboration and exchange) involved in the transactions and it is often difficult to examine the 'complementary resources' which are exchanged within a service system, for example, information resources. In addition, the literature indicates that the tools to create, track, and manage outsourcing business process opportunities are incompatible, slow, and difficult to use (S-Cube, 2008, 2009). To exasperate this, it is also reported throughout literature that critical business data is incorrectly collected, shared, standardised, or analysed to provide business intelligence (S-Cube, 2008, 2009). This study suggests that one solution towards modelling service performance analytics is to examine the relational structures to support service networks. Despite the volume of research which concentrates on complex business applications and modelling processes there are no research efforts to explore the implications of relational structures on service network performance. In addition, Camarinha-Matos and Afsarmanesh (2006), report that based on an analysis of past modelling efforts there appears to be a significant lack of understanding among practitioners and researchers on the "*comprehensive spectrum of suitable modelling processes, tools, and methodologies*" (p. 4). Technology is considered an essential factor towards the virtualisation and success of service networks. However, as we promote the need for IT infrastructure across service networks, we know relatively little regarding the influence of IT on service performance and strategic advantage. This is emphasised in Carr's (2004) infamous book on, "Does IT Matter? Information Technology and the Corrosion of Competitive Advantage." He reports that although IT has been widely adopted by business, there is still know little known about what influence IT has on service performance and competitiveness. Organisational processes and indeed their structures have become less transparent with the emergence of service systems. To emphasise the importance of modelling service network structures, Papazoglou et al., (2006), states that there is a need to understand business processes and organisational structures, with the aim to identify organisations '*pain points'* and identify potential solutions that can be applied to correct them. Within a new service network business model, many of these pain points exist as Cross and Parker (2004), explain that little attention has been paid to access the effectiveness of strategic partnerships of strategic developments or to the value of their networked relationships. Thus the relational structure of service networks shared amongst organisations to support business operations may prove to be the key to modelling service networks and their performance. We identify the need to visualise and understand the relational contributions of service structures to further enhance decision making tasks while restructuring service network business processes. A major consequence of being unable to model service performance is that managers cannot determine the structure and value of the overall service eco-system or *"…capture the adaptive and evolutionary characteristics of a value network …* [and] *the nesting of supply chains with larger and more encompassing value networks*" (Lusch at al., 2010). We posit that the implications of relational structures and service behaviour allow us to develop the business transaction paradigm and in particular, in service network performance analytics.

8. Performance Analytics

A service network is a complex system which relies on the harmonisation of numerous actors. Service performance is often influence by external entities causing structural variability across a service eco-system which impacts of the networks characteristics and ultimately, its performance. Therefore, it is critical that service managers gain a thorough understanding of what influences service performance for two main reasons; firstly to enhance service management decision-making tasks (service management), and secondly, to feed this information into service requirements engineering (service computing). While this study will later discuss performance using key performance indicators (KPIs), we will also focus on network analysis considering there are five other main exploratory analytical methods to examine performance; relational (interaction), attribute (properties of vertices and edges), position, structure, and dynamics analysis. However, before we attempt to measure service network though performance analytics, we are reminded of Hubbard's (2007) advice to first question how and what gets measured as it has some conceivable effect on decisions and behaviour (p. 43):

1. What is the decision this is supposed to support?
2. What really is the thing being measured?
3. Why does this thing matter to the decision being asked?
4. What do you know about it now?
5. What is the value to measuring it further?

As the questions listed above allude to, managers must rethink (design, innovate, deliver, and support) new strategies and possible structures to transcend their competencies which impacts on performance across service networks (Spohrer and Maglio, 2009). This includes technology, network topology, human behaviour, business strategy, service design, and economics (Rai and Sambamurthy, 2006). More specifically, managers must pay close attention to how service management is conceptualised (capabilities, structures, and processes) and how behaviour is orchestrated to interact and innovate service development (Rai and Sambamurthy, 2006). Table 4 below, provides a holistic view of the interchange between 'soft' and 'hard' views of the service system.

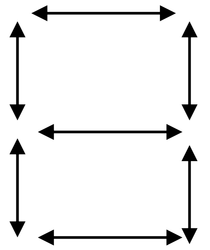
	"Soft" **"Hard"**
Service Package (core and peripherals) Interaction and the delivery process Whole system (image, culture, 'the club')	

Table 4 Socio-technical view of service networks (adapted from Normann, 1991)

Service interaction is a functional process as competencies are typically exchanged between actors. Actors can refer to a 'soft' and 'hard' socio-technical view of service systems (as identified by adopting ANT). Applying this business logic the service actors and service competencies draws our attention towards the relationship or tie which determines the exchange patterns within a service network. Therefore, service (actor) interaction patterns should be possible to model and provide insight on how specific actor relations enable or inhibit service business processes. We can also categorise the type of relationship within performance analytics and KPIs. It can also provide greater insight within the service exchange process and the 'value' of the exchange, for example, information and financial data. If managers fail to report on the influence that each independent level plays on other levels, they may be applying incorrect performance measures. For example, there are three main types of performance measures (table 5 and figure 2):

Performance Measure	Explanation	Examples
Key Result Indicators (KRIs)	*Examine* the past to determine how a service has performed, for example, sales last month.	• Customer satisfaction • Net profit before tax • Profitability of customers • Employee satisfaction • Return on capital employed
Performance indicators (PIs)	*Inform* what you ought to do to enhance service.	• Profitability of the top 10% of customers • Net profit on key product lines • Percentage increase in sales with top 10% of customers • Number of employee participating in the suggestions scheme
Key Performance Indicators (KPIs)	*Prescribes* what you ought to do to increase service performance.	• Utilisation of assets, optimisation of working capital • Increase customer satisfaction, targeting customers who generate the most income • Deliver in full on time, optimising technology, effective relationships with key stakeholders Empowerment, increased expertise and adaptability

Table 5 Main Types of Performance Measures (adapted from Parmenter, 2007)

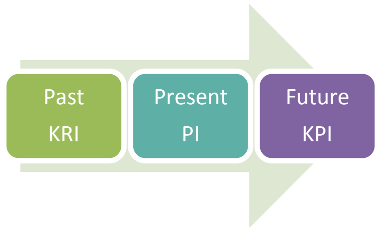


Figure 2 Performance Measures and Time

As summarised in table 5 above, and illustrated in figure 2 above, performance indicators (KRIs, PIs, and KPIs) analyse how key activities influence service performance and adopt certain views of performance (i.e. past, present, and future). Service delivery systems also distinguish five main factors which are invariably influenced by the physical setting of technical tools to deliver a service (Normann, 1991; p. 98): cost rationalisation, quality enhancement, beneficial customer linkages, behavioural implications, and technology adaption. These tend to blend or overlap in most cases in the deliverance of a service, making it more complex to analyse. The affordance of service oriented applications also places questions as to the effects technology has on service behaviour, an area often disregarded, as technology can fulfil a key function creating the desired human behaviour; but desired by whom? Technology affects many if not all the other components in the service (Norman, 1991). Since services involve social actions, technology must be accompanied by other changes in the service management system.

Services which have implemented performance management models (for example, IT Service Management – ITSM[1]) are not supported through a well defined or benchmarked strategy as each management strategy has its benefits and challenges. In alignment with performance analytics, the Information Technology Infrastructure Library (ITIL[2]) has suggested to answer four important questions. It is evident that these questions relate directly back to CSFs, KRI, PI, and KPIs. The first question is "*where do you want to be?*" This suggest that organisation must be committed to service transformation and cooperated to meet the business objectives, mission, and vision. The second question, "*where are we now?*" may be a difficult question to answer but managers must identify where changes are needed, for example, people, process, practice, technology/technical infrastructure, and data (i.e. metrics) to steer the service towards the service vision. The third question asks, "*how do we get to where we want to be?*" which requires a more detailed plan including a top-down (process-orientated technical infrastructure) and bottom-up (influence the development of processes) of a service system (see figure 3).

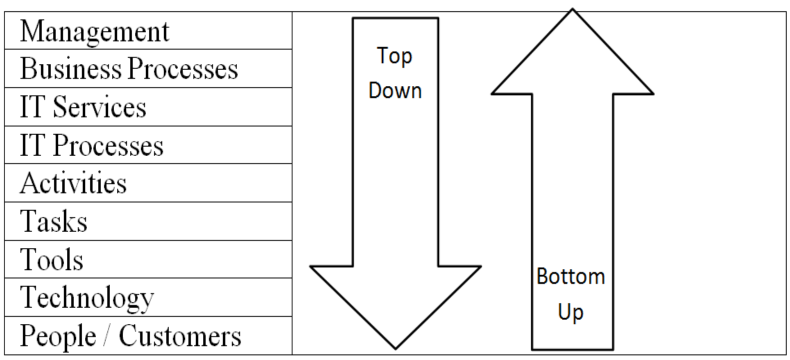


Figure 3 Approaches to Performance Analytics

[1] ITSM: http://www.itsm.info/ITSM.htm
[2] ITIL: http://www.itsm.info/ITIL.htm

The top-down approach is mainly preferred by large organisations and is characterised by defined processes and by the design and creation of a technical infrastructure to support the processes. The bottom-up approach is typically preferred by small service networks and is driven by the advantages of using current tools to assist in defining the required processes. A quick return on investment is considered important and deploys a process-supported infrastructure. The fourth and final question is "*how do we know when we have arrived*?" This is a critical question as it determines the success criteria (a major factor within service science). Therefore, it is paramount that management focus on a number of performance metrics. Regardless of the criteria for success, it should have some direct or inferred business value and reflect a continually supportive role in service networks units.

Although often considered problematic, gathering data on the health (e.g. structural, positional, communication, functional, relational, decision, interactional, and behavioural) of a networks performance is very important (Watts, 2004). This study will further explore the development of KPI for each of these categories and develop a framework upon which to evaluate service performance analytics. Organisations must attempt to shape and exploit service data if they want to strengthen their competitive position and knowledge to enhance their performance (Normann, 2001; Hassan, 2009). One of the major problems, as outlined by Becker (2007), is that managers are faced with a serious issue of how to manage "a completely invisible asset". These invisible assets may be referred to as intangible assets which are often difficult to model and consequently, often unaccounted for. Performance analytics plays an important role in service networks as customers are afforded smarter choices through the availability of technology allowing them to compare services. Turning performance data into information allows customers to make informed choices on service value and reputation. The reverse is also true. Gathering information on customer interaction with a service provider provides managers with rich insights as to how a service network is performing to meet customer needs, how service infrastructure supports service demands, and emerging service markets. This allows mangers to make faster and more informed decisions (by reducing uncertainty) on network strategies and enable them to model service interaction and exchange patterns and open opportunities of network alliances and creating 'smart service' systems. This is also evident with the need to adopt a key performance indicators (KPI) strategy.

9. Key Performance Indicators

"*What gets measured gets managed*" – Peter Drucker

Key performance indicators (KPIs) are quantifiable measures of an organisations progress to meet specific goals. KPIs also assist managers in decision making to determine the right course of action. When we incorporate network science approaches, the level of dimensional support across the process structures is expressed in several forms including, structural, functional, compositional, and behavioural. Often these dimensions are taken for granted and overlooked although this information provides both tangible and intangible metrics on service network performance. Sifting through departmental and cross-organisational conflicting objectives clutters manager's ability to extract key performance information (Glenn, 2009). There are several reasons why service metrics often fail, for example, service networks may use incorrect metrics which do not measure the business value of the network. Incorrect metrics may also mean that the performance findings are not actionable as probing for a complete analysis of the network is more difficult to collect data. In other cases, managers may set poor performance targets and fail to implement incentives or penalties to enhance the service performance. Another reason may include the over emphasis on service cost over business benefits. Within a service environment, SLA often governs the level of performance and quality of service which may provide us with more insight on what KPIs supports the service processes. Parmenter (2007), illustrates how manages might attempt to introduce a KPI strategy in an organisation (figure 4)

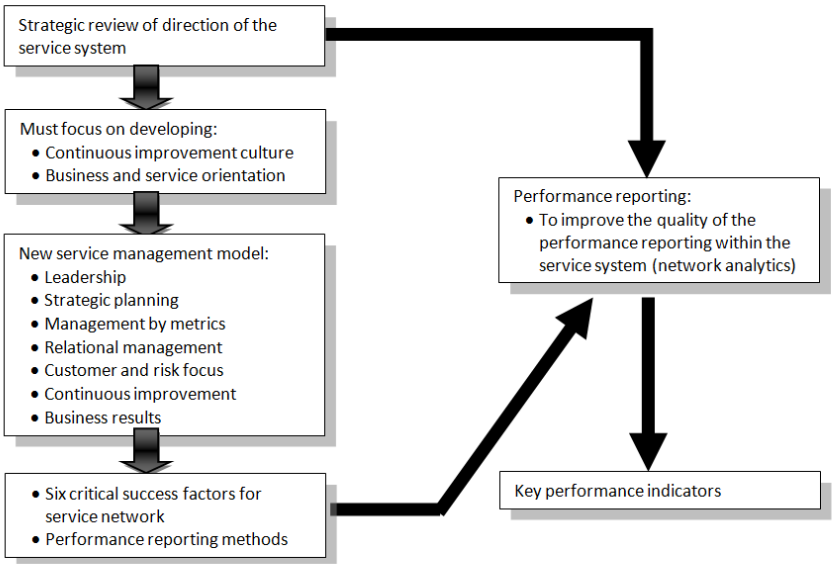


Figure 4 Introducing Key Performance Indicators (adapted from Parmenter, 2007)

As figure 4 above illustrates, introducing KPIs requires a carefully planned strategy; a strategic vision, continuously improving business and service orientation, adopting a new business model, identifying critical success factors, reporting performance, and evaluating how whether performance meets the predetermined KPIs. Many services are exceedingly complex phenomena which can be conceptualised in several different ways (Normann, 1991). Taking a qualitative perspective and trying to really understand primarily what relational structures mean in service network, how they evolve, and then try and address and look at how they change with the impact of IT and service performance from a quantitative perspective. The relationships which exist between these services can determine the service innovation and operations efficiencies across networks. This will also allow us to identify the critical success factors (CSFs) which enable (KPI) or inhibit business processes. Papazoglou (2003), draws our attention to the focus of the current practice of business transactions, and the lack of insight into the behaviour or the relationships of transactions between trading partners which can enhance their semantic value when transaction functions are combined. Sifting through departmental and cross-organisational conflicting objectives clutters manager's ability to extract key performance information (Glenn, 2009). Freeing up resources to develop value-added information is critical to managerial activities (e.g. rapid decision making and execution). To address these issues we must uniquely define the business KPIs. KPIs allow us to measure the success of goal achievement and to generate insight to discover how service performance and value may be enhanced. Characteristically, service network KPIs should be simple for decision making, relevant to unique (service-dominant) business models, present timely results, useful, and instant for actionable insights. Here, one is reminded of services seeking the right balance or requisite variety between 'use, usage, and usability' (Keen and Sol, 2008) of their resources and processes through service-oriented approaches. In addition, Parmenter, (2007) identifies seven key characteristics of KPIs:

1 Nonfinancial measures (not expressed in currency)
2 Measured frequently (e.g. daily, or 24/7)
3 Acted on by the CEO and senior management team
4 Understanding of the measure and the corrective action required by all staff
5 Ties responsibility to the individual or team
6 Significant impact (e.g. effects most of the core CSFs and more than one balanced scorecard perspective)
7 Positive impact (e.g. affects all other performance measures in a positive way).

Determining service behaviour involves qualitative behaviour analysis (across many dimensions such as structural, functional, compositional, and behavioural; for example, see Camarinha-Matos, 2006, pp. 11). In addition, Kaushik (2007), reports that KPIs are quiet limited in what they can present to manager or analysts for strategic direction, i.e. they present what happened. This has led to the slowly emerging concept of Key Insights Analysis (KIA). The concept of KIAs will be further explored in regards to service analytics, i.e. how and why specific service behaviour on a network occurred but we incorporate it within the concept of KPIs and performance simulation. We also encapsulate this when we refer to the notion of 'performance analytics'. We adapt Parameter's (2007) model to apply it within a service environment (figure 5) as follows:

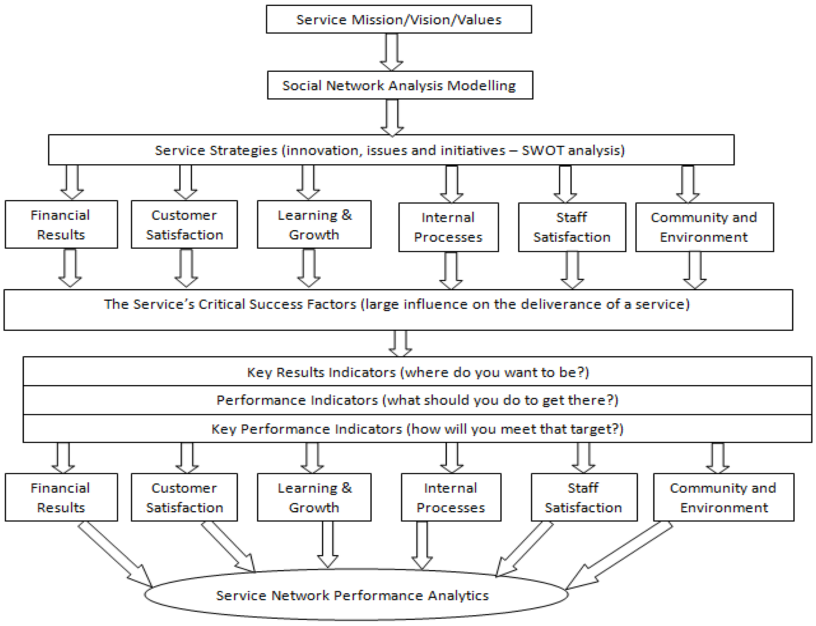


Figure 5 The Journey towards to Performance Measures (adapted from Parameter, 2007)

Within a service environment, it is paramount to begin the process of establishing performance measures by exploring the nature of the service mission, vision, and values. Considering services are typically unique in many ways, each service must determine their mission, vision, and values. A service mission may be a philosophical view and never be reached, for example, IBM adopts the following mission statement:

> At IBM, we strive to lead in the invention, development and manufacture of the industry's most advanced information technologies, including computer systems, software, storage systems and microelectronics. We translate these advanced technologies into value for our customers through our professional solutions, services and consulting businesses worldwide."

In addition, mangers must develop a vision (often an intangible or philosophical view) on what they must achieve in order to successfully meet their goals, for example, IBM adopts: "*solutions for a small planet*". Services must also devise strategies to achieve their visions. Within the service environment, managers need to identify areas to introduce service innovation, service initiatives, and identify issues which may present opportunities or threaten service sustainability. This may be achieved through a SWOT-like analysis (strength, weaknesses, opportunities, and threats) of the service environment while adopting the balanced scorecard critical success factors; financial results, customer satisfaction, learning and growth, internal processes, staff satisfaction, and community and environment. These may be adapted to suit a service environment and identify KPIs to examine service competencies, relations, and resource exchange.

Freeing up resources to develop value-added information is critical to managerial activities (e.g. rapid decision making and execution). To address this we must uniquely define the service KPIs which may be determined by modelling the implications of relational structures on service performance. The four key operational metric categories may be summarised as volume (what gets done), quality (compliance with requirements), responsiveness (timeliness to deliver a service), and efficiency (cost and effort to deliver a unit of service). Understanding the influence of relational structures allows us to explore, for example, number of vertices, number of edges, directed and undirected edges, positions, adjacent (in and out) vertices, degree, direction, and other metrics which will be borrowed from network science theory where applicable to service network performance. The KPIs will represent data structures which will be illustrated using a graph. The graph will present us with an overview of the KPIs which allow us to examine the success of goal achievement and to generate insight of the implications of relational structures on performance within the service network. Network analysis allows us to explore questions such as, what is the optimal network performance? This research will explore this question a little further in this document (i.e. social network analysis section). While the study explores KPIs, Parmenter, (2007) suggests that we need to ask the following key questions:

1. Who owns the metric?
2. Where will the data be acquired and how often?
3. How might the raw data be manipulated (normalised) to allow more equivalent comparison over time?
4. How often should the metrics be reported and analysed for decision making.?

It is critical that managers attempt to evaluate the metrics for gaps, alignments and conflict across the service network, or perhaps the eco-service system. In addition, to successfully align the metrics, one must determine how metrics interrelate at various management levels, i.e. vertical alignment and horizontal alignment (positions in the value) contribute towards the service strategy. Parmenter, (2007), provides an example of this and provides an outline of the tree format which makes it more comprehensive (table 6):

Exploring the interrelation of key performance indicators:

1. Percentage of loyal customers (cooperate level)
   1.1. Customer service satisfaction (cooperate level)
      1.1.1 On-time deliveries (operations level)
2. Service reliability (operations level)
   2.1. Maintenance done on-time (maintenance department level)
      2.1.1. Friendliness of service staff (operations level)
3. Training effectiveness(training level)

Table 6 Interrelation of KPIs at various levels

The interrelation of KPI’s plays a significant role in the process of evaluation. It is important that managers have a clear understanding of how processes impact of the overall service at various levels. Through the use of KPIs, organisations can gain continuous and insightful feedback on how business processes are actually being executed, and where “gaps” or “pain-points” may exist. This is important, as Bender-deMoll’s (2008) explains that organisations vary in many ways, and not only in their size and budget available, but also in “*how well connected they are, whom they work with, and how closely integrated they are with the groups they are aiding*” (p. 2). Many studies have reported the need to investigate the interaction between systems through the introduction of newly designed processes to improve service health. Reporting KPI is also an important task and directly impacts in the successful deployment of a service performance analytics strategy. Parmenter (2007) provides a list of instructions when recording and reporting on performance measures. These are as follows:

1. Description and explanation of the performance measure and calculations
2. The type of performance measure (KRI, PI, KPI) and person responsible for them
3. System where data is sourced from or to be gathered
4. Refinements that may be required to produce “real-time” information

5. Which business scorecard (BSC) perspective(s) the performance measure impacts
6. Recommended display (type of graph)
7. Linkage of measures to CSFs
8. The required delegated authority that staff will need to have in order to take immediate remedial action

These may be recorder as outlined in table 7 below:

Name of performance measure	Calculation of measure	Type of PM	Person responsible	System where data is going to be gathered	BSC Perspective	Recommended display	Frequency of measurement; 24/7, weekly, monthly	Linkage to CSFs	Team xx	Suggested target	Required reliability/accuracy (± 5%, ±10%, ±20%)	Estimated time to gather information (15 mins, 1 hour, 1 day, >1 day)
Number of initiatives implemented from the quarterly rolling client survey	Number of initiatives implemented out if the total arising from survey	Performance Indicator	Staff Initials	Word	Customer Satisfaction	Number	Weekly	Retain Key Customers Increase repeat business	Y	All by 3 months post survey	±5%	5 mins
……….	……….											

Table 7 Service Network Performance Analytics (adapted from Parmenter, 2007)

To build on this reporting format, the next section offers a discussion on the complementary application of SNA on modelling service analytics.

10. An Overview of Social Network Analysis

This section sets out to describe the suitability of social network analysis (SNA) as a technique which complements the research method of exploring the implications of service relational structures on service performance. In addition, this section discusses the need to describe a class of data to focus the research (i.e. performance analytics), which is considered essential to develop a formal way to define and characterise what will be observed and how it will be expressed (Freeman et al., 1992) to view the world during data collection. SNA stems from the network science discipline. Lewis (2009) defines network science as the study of the theoretical foundations of network structure/dynamic behaviour and its application to many subfields (such as SNA). In addition, to incorporate the dynamics of networks, we must avail of the information which informs us how the service interaction resulted in a specific outcome. Therefore it consists of both theory and application. Thus, we can define the structure of a system in terms of abstract mathematical objects called vertices (nodes) and edges (links). In addition, Lewis (2009) suggests that the best way to describe a network is by what it does, i.e. "*the study of the structure of the collection of nodes and the links that represent something real*", and the "*study of dynamic behaviour of the aggregation of nodes and links*" (p. 6).

SNA is an approach and set of techniques which studies the exchange of resources and competencies (for example, information) among actors. SNA focuses on patterns of relations among nodes such as people, groups, organisations, or information systems (Berkowitz, 1982; Wellman and Berkowitz, 1988; Scott, 1991; Wasserman and Faust, 1994). SNA also demonstrates the value of ties and relationships between each node to provide a visual and mathematical representation of interaction and exchanges which influence behaviour. Managers realise that the key to continued success is within their understanding of how workflows and business processes can be optimised (e.g. Papazoglou, 2002). Balkundi and Kilduff (2006), report that SNA may allow organisations, in financial trouble, to gain vital insights and discover survival prospects. Thus, additional focus should be placed on tailoring the business model and methods to guide and support the processes of monitoring and mapping KPIs across service networks (system, goals, and method patterns). Kawalek and Greenwood (2000), describes an abstract model of an organisation, and how we can develop our understanding of value through the addition of three models when applied to a service network (which also relates back to KPIs):

1. ***A model of the system***: a high level, structural view of actor interactions (who and/or what interacts)
2. ***A model of goals***: having identified patterns of interaction in the model, how can we describe the interactions (why do they take place)
3. ***A model of methods***: having identified what interacts and why, a model is developed to determine why and how goals are achieved.

To add a fourth step to Kawalek and Greenwood (2000) abstract model, from a service perspective, it would be extremely useful to implement a "*model of action*", i.e. a model which would allow us to explore strategic possibilities to simulate a "what-if" approach to understanding the influence of each relationship across business processes. A fifth model would include a "*model of evaluation*" which introduces service performance analytics (as depicted in figure 6 below):

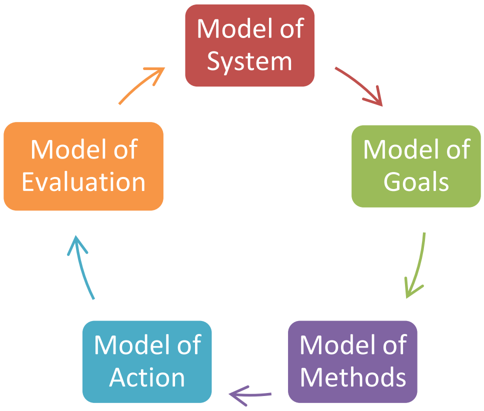


Figure 6 Abstract View of Service Network Analysis

Such an approach as illustrated above is necessary as Hassan (2009), demonstrates that by studying IT-enabled processes, we can identify the contribution of IT to business process success, or improved performance. In addition, while adopting the SNA approach, Lundqvist (2007) describes SNA as a method for detecting, describing, and analysing relationships. Another benefit of SNA is its ability to provide a methodology to gain deeper insight of how structural regularities influence behaviour (Otte and Rousseau, 2002). SNA assumes that actors (i.e. services nodes) are interconnected, with real consequences for behaviour and performance. Structures may be altered to optimise the networks outcomes. Therefore, SNA is a very fitting methodology to deploy within this research to uncover more "truths" as to service activities, interaction, and exchange. In addition, SNA complements the worldview this research adopts using ANT for service networks.

There is a large body of literature which suggests that SNA can present us with a unique method to model and monitor the contributory value of network actors and infrastructure (for example, Tichy et al., 1979; Berkowitz, 1982; Wellman and Berkowitz, 1988; Scott, 1991; Wasserman and Faust, 1994; Hansen, 1999; Watts, 2004; Hassan 2009). Managers have ignored the "*dynamic characteristics of networks and the ways that dynamic qualities of networks affect organisations' flexibility and change*" (Cross and Parker, 2004; pp. 133). This has unavoidably led to organisations failing to capture the 'health' of their service networks performance (for example, behavioural, functional, and structural) and the overall contributory value of service linkages (relational structures). SNA is an approach and set of techniques which studies the exchange of resources (including competencies) and behaviour among actors. It focuses on exchange patterns of relations among nodes such as people, groups, organisations, business processes, information systems or combinations thereof (Freeman et al., 1992). SNA also affords us the opportunity to model the relational ties between each node to simulate the service network behaviour to provide a visual and mathematical representation of interaction and exchanges which influence service performance. To understand the dynamic nature of services networks and its impact on service performance, it is critical to explore the underlying principles in service behaviour and analyses both how and why services perform in a specific manner. Spohrer et al., (2007), posit that the success of service science will be achieved through the introduction of general theories of service interaction and co-creation of value. Service science is also an attempt to explore the value co-creation of interactions between service systems. As service networks continue to grow, understanding the dynamic resource exchange and the value of service relationships between service systems is of critical importance. As discussed earlier, a service is often referred to as "*protocols plus behaviour*" (Spohrer et al, 2007). Failing to measure the mechanics behind the behaviour and 'value-exchange' of service networks (i.e. their relational structures) inhibits our capability to examine real business process performance and additional opportunities.

11. Applying Social Network Analysis to Service Networks

In recent years there has been significant interest in our ability to effectively and efficiently manage and (re)engineer services. It is clear throughout literature that manager's continue to face serious issues in managing 'a completely invisible asset' (i.e. service network) which inhibits their ability to monitor and exploit the value of service innovation. Services must gain continuous and insightful feedback on how business processes are actually being executed, and where 'gaps' or 'pain-points' may exist. This enables BPM to overcome three major problems:

1. The need to isolate and measure the impact of IT on service networks in order to plan and design how the technology should support the business process across service eco-systems (Hassan, 2009).
2. The need to measure the success of IT-enabled BPM efforts as they are being implemented through KPIs (Hassan, 2009).
3. Determine how service-orientated process patterns influence the configurability of service system networks (i.e. service evolution).

In addition, Cross and Parker (2004) summarise the common SNA applications including, supporting partnership and alliances, assessing strategy execution, improving strategic decision in top leadership networks, integrating networks across core processes, promote innovation, ensuring integration post-merger or large scale change, and developing communities of practice. Thus, BPM can also benefit from the application of SNA in service modelling. More notable, SNA can support BPM to discover business process dynamic behaviour while identifying where strengths, weaknesses, opportunities, and/or threats lie across a service network and service eco-system using SNA metrics. Measuring business networks provide valuable insights on the operating status of a service network and determine whether change may be required, or provide knowledge where change may cause further problems through SNA simulation. Figure 7 below illustrates a simple example of a SNA map.

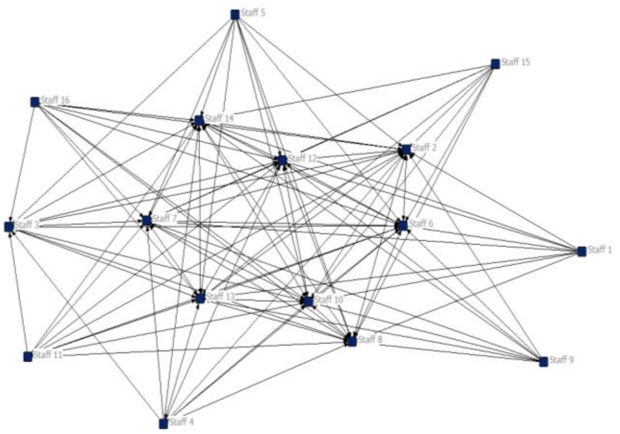


Figure 7 Example of SNA Map

Within SNA literature, there are a number of metrics which lend nicely towards service network analytics (see table 9). For example, the density of service network allows us to examine the ratio of service relations when compared to the maximum of possible relations (Wasserman and Faust, 1997). The average relational distance within the whole network is calculated by determining the average shortest path between all vertices or actors. Depending on the nature of the service network, a short distance is best to transmit information accurately and timely, for example, customer service, financial, or medical networks. Cross and Parker (2004), suggests that long(er) relational structures generate slow and inaccurate information channels. Managers may also examine the degree of actors which explores the number of edges (links) which connect to a particular node. Business process modelling and the evaluation of various scenarios for service improvement are the main driving factors of restructuring business processes. SNA allows us to graphically capture organisational interaction, and can provide us with an insight into how people's understandings of business process through service interactions. Thus, SNA provides an excellent methodology to offer managers a more simplified, practical, and reusable framework. Figure 8 below, illustrates how SNA complements service performance analytics and supports the development of service science (service management and service computing) while under the guidance of ANT as a foundation for this research.

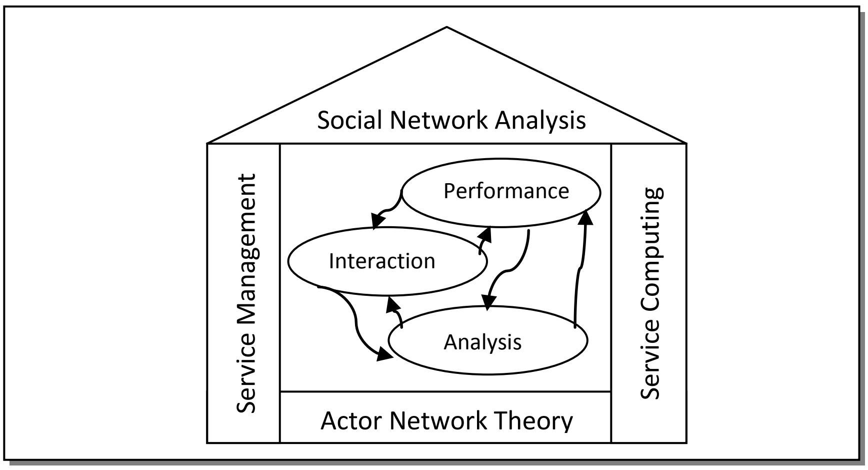


Figure 8 Service Network Performance Analysis Approach

As illustrated above, SNA will present us with a technique which allows us to monitor service behaviour (performance, interaction, and analysis). SNA also presents the opportunity to execute position analysis (for example, centrality to identify important actors involved in service relationships) at a micro (the service) and a macro (service eco-system) of a network and explore network characteristics. Both the direct and indirect service relations will be considered. Managers may analyse a service network to determine if a node/actor is a source or drain within the service.

Other network measures may include network density, average distance, and average degree metrics. These metrics will be among the service relational structures measures reported in our undertaking of service network analytics. The term ‘relational structure’ may be used to describe a “*bundle of intuitive natural language ideas and concepts about the patterning*” (Freeman et al., 1992; p. 12) in service relations among organisations. Freeman et al., (1992; p.12) add that a ‘social network’ is “*a collection of more or less precise analytic and methodologically concepts and procedures that facilitate the collection of data in a systematic study of such patterning*”. More notable, from this research’s perspective, Stanley Milgram conjured up the notion of small-world network to understand how network topology influences behaviour. Thus, we can develop an understanding of a service network by describing its structure (nodes and links) and its behaviour (what the network does as a result of interactions among the nodes and links). This has an important application to the management, engineering, and design of service networks. Network analysis emphasises the relations which connect the node positions within a system, and “*offers a powerful brush for painting a systematic picture*” of a global structure and their interaction (Knoke and Kuklinski, 1991; p. 173). Therefore the organisation of structural relations (emergent property of the connection and the exchange process) or attributes (intrinsic characteristics, e.g. value of an exchange) becomes a central concept to analyse a networks structural properties. Relational structures capture emergent properties which affect the systems performance and behaviour (Knoke and Kuklinski, 1991). Simply put, Salancik (1995), explains that “*a network theory about organisations should also be able to say how network properties themselves generate the properties of organisations*” (p. 349).

The major characteristics of attribute analysis are that the unit of analysis is the individual actor and the variable describes the behaviour of the network actor. Normann (2001) suggests that co-ordinating efforts by different actors towards a common whole is not new, for example, he explains how economics describes the logic leading to complementary specialisation as that of ‘competitive advantage’. Normann (2001) adds that what is new is not co-production but the way it is now expresses itself in terms of role patterns and modes of interactivity and organically reshapes co-productive roles and patterns especially within service networks. The new roles which result in service interaction defy what was once understood as the ‘value chain’ within the goods-dominant mindset. If we focus on the service-dominant era, we can apply Lewis (2009 p.20-21) list of the key characteristics of network science which are applicable in the modern service era:

Characteristic	Description
Structure	Not a random collection of nodes and links and have a distinct format or topology which suggests that function follows form.
Emergence	Network properties are emergent as a consequence of a dynamic network achieving stability.
Dynamism	Dynamic behaviour is often the result of emergence or a series of small evolutionary steps leading to a fixed-point final state of the system.
Autonomy	A network forms by the autonomous and spontaneous action of interdependent nodes the “volunteer” to come together (link), rather than central control or central planning.
Bottom-up Evolution	Networks grow for the bottom or local level up to the top or global level. They are not designed and implemented from the top down.
Topology	The architecture or topology of a network is a property that emerges over time as a consequence of distributed – and often subtle – forces or autonomous behaviours of its nodes.
Power	The power of a node is proportional to its degree (number of link connecting to the network), influence (link values), and betweenness or closeness; the power of a network is proportional to the number and strengths of its nodes and links.
Stability	A dynamic network is stable if the rate of change in the state of its nodes/links or its topology either diminishes as time passes or is bounded by dampened oscillations within finite limits.

Table 8 General Principles of a Network (Lewis, 2009)

SNA may be simply described as an x-ray of the organisational service structure which highlights the importance relational structures to support service performance. According to Tichy et al., (1979), network analysis is concerned with the structure and pattern of these relationships and seeks to identify both their causes and consequences (p. 507). Therefore, organisations can be viewed on an abstract level as social groupings with relatively stable patterns of interactions over time. However, this is not the case within a service environment and we require techniques to model the system relational structures though a coherent framework and methods of analysis to capture both emergent process patterns between a specific set of linkages and their properties among a defined set of actors. Tichy et al., (1979) provides an overview of network concepts and network properties as listed in table 8 which are considered fundamental to service network performance.

Property	Explanation
Transactional Content	Four types of exchanges: 1. Expression of effect (e.g. initiate a transaction) 2. Influence attempt (e.g. negotiating a SLA) 3. Exchange of information (e.g. terms and conditions) 4. Exchange of goods and services (e.g. payment)
Nature of links	
1. Intensity	The strength of the relations between individuals (i.e. intensity of service interactions)
2. Reciprocity	The degree to which a relation is commonly perceived and agreed on by all parties to the relation (i.e. the degree of symmetry)
3. Clarity of Expression	The degree to which every pair of individuals has clearly defined expectations about each other's behaviour in the relation, i.e. they agree about appropriate behaviour between one another (i.e. SLA)
4. Multiplexity	The degree to which pairs of individuals are linked by multiple relations. Multiple roles of each member (e.g. consumer, supplier, negotiator, etc) and identifies how individuals are linked by multiple roles (the more roles, the stronger the link).
Structural Characteristics	
1. Size	The number of individuals participating in the network (i.e. service eco-system)
2. Density (Correctedness)	The number of actual links in the network as a ratio of the number of possible links
3. Clustering	The number of dense regions in the network (i.e. network positioning, structural holes)
4. Openness	The number of actual external links of a social unit as a ratio of the number possible external links
5. Stability	The degree to which a network pattern changes over time (i.e. level of innovation)
6. Reachability	The average number of links between any two individuals in the network.
7. Centrality	The degree to which relations are guided by the formal hierarchy
8. Star	The service with the highest number of nominations
9. Liaison	A service which is not a member of a cluster but links two or more clusters
10. Bridge	A service which is a member of multiple clusters in the network (linking pin)
11. Gatekeeper	A star who also links the social unit with external domains (i.e. knowledge diffusion and service network analyst)

12. Isolate	A service which has uncoupled from the network.

Table 9 Organisational network analysis concepts and network properties

The transactional content explores what is exchanged by actors (e.g. information) within the network. The nature of the links considers the strength and qualitative nature of the relation between two or more nodes, while the structural characteristics examine the overall pattern of relationships between the actors, e.g. clustering, network density, and special nodes on the network are all structural characteristics. Watts and Strogatz (1998), report that real-world networks are neither completely ordered nor completely random, but rather exhibit properties of both. In addition, they claim that the structure of network can have dramatic implications for the collective dynamics of a system, whose connectivity the network represents, and that large changes in dynamic behaviour could be driven by even subtle modifications to the network structure.

Knoke and Kuklinski, (1991) discuss the concept of relational form which refers to the properties between pairs of actors (dyads) that exist independently of specific contents, for example, the intensity or strength of a link between actors, or the level of joint involvement in an activity. Knoke and Kuklinski, (1991; p. 177) lists the common types of relational content:

1. *Transaction relations*: actors exchange control over physical or symbolic media, for example, a purchase.
2. *Communication relations*: linkages between actors are channels by which messages may be transmitted from one actor to another in a system.
3. *Boundary penetration relations*: the ties between actors consist of constitute subcomponents held in common, e.g. a board of directors.
4. *Instrumental relations:* actors contact one another in efforts to secure valuable goods, services, or information.
5. *Sentiment relations*: actors express feelings towards one another.
6. *Authority/power relations*: usually occur in complex formal organisations governed by rules and regulations.

Therefore the organisation of structural relations (emergent property of the connection, the exchange process) or attributes (intrinsic characteristics, e.g. value of an exchange) becomes a central concept to analyse a networks structural properties. Relational structures capture emergent properties which affect the systems performance and behaviour (Knoke and Kuklinski, 1991). From a service network perspective, we can identify recent advances that extend network analysis towards dynamic analysis and multi-actor networks. For example, Carley (2003) explores three key advances: the meta-matrix (focus on people, knowledge/resources, events/tasks, and organisations), treating ties as probabilistic, and combining social networks with cognitive science and multi-agent systems. These are outlined in table 10 below (and highlight the importance of adopting ANT).

	People	**Knowledge/ Resources**	**Events/Tasks**	**Organisations**
People	Social network (motivation to interact, and change in access)	Knowledge network (learning acquisition)	Attendance network	Membership network (mobility recruitment)
Knowledge/ Resources		Information network (discovery and analogical reasoning)	Needs network (innovation)	Organisational capability
Events/Tasks			Temporal ordering	Institutional support or attack (re-engineering)

Organisation				Inter-organisational network (alliance or coalitions)

Table 10 - Meta-Matrix (Carley, 2003)

Table 10 above summarises the various dimensions which add to service network complexity. Carley (2003), lists a set of measures which are not correlated, although they are key to characterise dynamic networks. These include; size of the network (number of nodes), density (number of ties or possible ties), homogeneity in the distribution of ties (the number of clusters, and variance in centrality), rate of change in the nodes, and rate of change in the ties. SNA assumes that actors are interconnected, with real consequences for behaviour and performance. Structures may be altered to optimise the networks outcomes which present an opportunity to model service network analytics. In addition, Durland and Fredericks (2005) also support SNA and suggest that it stands apart from other methodological theories and focuses on the context and behaviour of relationships which is considered the blueprint of networks among actors making it an excellent technique for service network analytics.

12. Service Network Analytics

The affordance of Internet technologies to support the evolution of service economies has transformed businesses from local to global socio-technical network infrastructures. Service networks are complex, open, and dynamic systems through integrated end-to-end service systems. Managing service networks is a difficult task especially with the view to develop and model performance analytics. Business processes are largely influence by policy, service regulation standards, and compliance standards. However, simulating service performance within a dynamic environment is often overlooked and become presumptuous of managers although they have little insight regarding the mechanics of service networks. Thus, the main motivation here is to explore service network performance and optimisation from a practical and theoretical perspective to enhance service process management.

We are particularly interested to identify and develop KPIs as quantifiable measures of service network and borrow SNA metrics as service network analytics to understand service network behaviour. Service KPIs can assist managers in decision-making to determine the right course of action or to identify service network opportunities (for example, structural holes). The level of dimensional support across the process structures is expressed in several forms including, structural, compositional, functional, and behavioural. Often these dimensions are taken for granted and overlooked although this information provides both tangible and intangible metrics on organisational networks. The relationships which exist between these services can determine the service innovation and operations efficiencies across networks. This will also allow us to identify the critical success factors (CSFs) which enable or inhibit business processes using KPIs. Papazoglou (2003), draws our attention to the focus of the current practice of business transactions, and the lack of insight into the behaviour or the relationships of transactions between trading partners which can enhance their semantic value when transaction functions are combined. Figure 9 below provides a simple illustration of how managers should explore the core service principles, i.e. the CSFs of the service. Managers must ask, what are the core areas upon which strengthens the service network before they can identify KPIs.

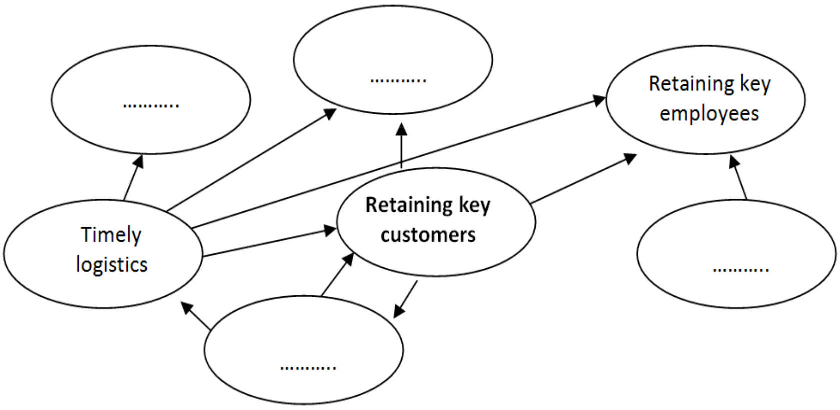


Figure 9 CSF Relationship Mapping

CSFs are also linked to one another and form a crucial insight as to how CSFs impact and influence the realisation of other CSFs. Managers can also assign weightings to reach CSF to indicate the importance placed on other CSFs to support one another. This allows mangers to develop robust methods of analysing the hierarchy of CSFs through relationship mapping (Parameters, 2007). The weightings to CSFs to highlight the importance or influence they play on one another. Managers can also cross-check the identified CSFs against the balanced scorecard perspectives (for example, see table 11 below) adopt to examine service performance.

CSF	Financial	Customer Satisfaction	Staff Satisfaction	Learning and Growth	Internal Process	Environmental/ Community
E.g. Timely Logistics	✓	✓	✓	✓	✓	Possible
E.g. Delivery of full and on time	✓	✓	Possible	✓	✓	✓
E.g. Retaining Key Customers	✓	✓			✓	✓
Etc ………..						

Table 11 Checking impact of CSFs against the Six BSC perspective

The importance of cross-checking CSFs with the balanced scorecard perspectives allows managers to further explore adopting a holistic view of the service network; financial, customer satisfaction, staff satisfaction, learning and growth, internal process, and environmental/community. In addition, managers must examine the service network topology and dynamic interaction. Once the CSFs have been identified, mangers must determine the relevance of each CSFs within a service network which report the six business scorecard perspectives. These may include some of the following factors (see table 12):

Business Scorecard Perspective	CSF Examples
Employee satisfaction	• Retention of key staff • Increase in employee satisfaction survey, active and well-supported social club etc.) • Supporting balanced working and nonworking life (respect different working styles/working hours) • Appropriate reward and recognition structure for all • Continuous learning environment • Promoting open decision making
Learning and growth	• Developing internal leadership • Increasing employee productivity • Developing strategic skills within management • Increase in adaptability and flexibility of staff • More open access for staff to strategic information
Customer	• Introduction of new services • Moving from satisfied to loyal customers (increasing the number of customer referrals, meeting customers' expectations in full) • Customer acquisition • Increased satisfaction with our key customers (timely service, reliability, quality, price) • Improving turnaround time • Increased repeat business (increased percentage of sales from key customers) • Ensuring delivery in full on time, all the time for key customers
Finance	• Optimising from profitable customers • Growth in revenue and product mix (new products, applications, customers, relationships, service mix, pricing) • Cost reduction/productivity improvement (reduce unit cost, improve channel mix, reduce operating expenses) • Optimal utilisation of assets and resources • Improved risk management (better forecasting, broaden revenue base, ect.)
Internal process	• Product leadership in industry • Enhancing operational efficiency, reducing cost per transaction • Increased linkages with key suppliers • Optimising technology • Completion on time and to budget measure • Encouraging innovation • Timely, accurate, decision-based information • Delivery in time, all the time
Environmental/community	• Support educational institutions • Enhance community interaction • Positive public perception of organisation

Table 12 CSFs though a Business Scorecard Perspective (adapted from Parmenter, 2007)

Table 12 above outlines some of the CSFs which managers typically identify with when they examine the core process which support the growth of their service. Implementing a successful performance analytics strategy relies on the successful coordination of several key tasks including identification of KPIs, monitoring, reporting, interpreting, planning, and reconfiguring business process to align performance with the service strategy. Therefore, the implementation of service process plays a critical role in service performance, but more importantly, reporting on process activity and interactivity. Each process must have a clear logical flow of which a process must establish ownership, define the scope, objectives and design of process, negotiate and determine each process metric and how technology supports its performance, and report on its performance in a timely fashion (i.e. automated reported mechanism). Many KPI strategies are viewed as being intrusive by people and consider it as a threat to their roles within a service (i.e. judged on performance). Therefore, it is imperative that management understand the scope of service change if it affects people or other services within the service eco-system. Here we focus on service network performance analytics. Performance may be mapped on retrieving information on process event and modelling their interrelationship.

13. Discussion and Conclusion

Understanding the value of service network relationships, especially from a technological perspective can prove to be extremely problematic. Moreover, the concept of network 'value' is often greeted with an expectation of vagueness or uncertainty, and tends to be avoided. One of the greatest concerns within today's service network landscape is the inability of business models to cater for the pace and dynamics of business. This places greater emphasis on the business model and the methods which facilitate service network contributions. If we accept Lusch et al., (2010) definition of a network value, failing to examine the service network value increases the chances of ignoring the spatial and temporal structure of largely loosely coupled value proposing actors which dynamically interact through 'institutions and technology' offers little insights on service performance. As a result, managers are unable to determine the co-produce service offerings, exchange service offerings, and the co-creation value (Lusch et al., 2010) within a service network. As a consequence, managers cannot determine the value of the overall service eco-system and to "*…capture the adaptive and evolutionary characteristics of a value network … [and] the nesting of supply chains with larger and more encompassing value networks*". Therefore, the value of service networks is an evolving characteristic of services as organisations adapt and learn to offer competitively compelling value propositions through liquefying resources. Within a service-dominant environment value is an evolving factor, so too must the relational structure which support value generation. Examining the implications of relational structures and service behaviour allows us to develop a paradigm that examines the mechanics of economic exchange and performance analytics within service network management. From this stance, this sets out to highlight the need to introduce service networks performance analytics and experiment with modelling techniques, for example, instance modelling, structural modelling, and behavioural modelling. We plan to develop a KPI framework which implements balance scorecard views and SNA metrics to establish a service network performance analytics (SNPA) matrix. The motivation for adopting this performance analytics view stems from Normann's (2001) concept of the 'principle of density', which is mainly driven by technology and the shift in managers mindsets in restructuring or reconfiguration of new 'opportunities'. The focus on service network relational structures acknowledges the fundamental role on the generation of value through the sustainability of service network relationships and performance.

14. References

1. Aalst, W.M.P. van der (2004). Business Process Management - A Personal View. Business Process Management Journal, Volume 10, Number 2, pp.248-253.
2. Aalst, W.M.P. van der., Weijters, A., and Maruster, L. (2004). Workflow Mining: Discovering Process Models from Event Logs. IEEE Transactions on Knowledge and Data Engineering, Volume 16, Issue 9, pp. 1128–1142.
3. Aalst, W.M.P. van der and Hee, K. (2004). Workflow Management: Models, Methods, and Systems. MIT press, Cambridge, MA.
4. Aalst, W.M.P. van der (2007). Trends in business process analysis: from verification to process mining. In J. Cardoso, J. Cordeiro, J. Filipe (Eds.). Proceedings of the 9th international conference on enterprise information systems. (pp. 12-22). Medeira, Portugal: INSTICC

5. Abe, T., (2005). What is Service Science? Research Report No. 246, The Fujitsu Research Institute, Economic Research Centre, Tokyo.
6. Afsarmanesh, H., Camarinha-Matos, L., M., (2005). A Framework for Management of Victual Organization Breeding Environments, in Proceedings of PRO-VE'05 – Collaborative Networks and their Breeding Environments, Springer, Valencia, Spain, 26-28 September, pp. 35-48.
7. Agrawal, R., Gunopulos, D., and Leymann, F. (1998). Mining Process Models from Workflow Logs. In Sixth International Conference on Extending Database Technology, pp. 469–483.
8. Auerswald, P. (2009). Creating Social Value. Stanford Social Innovation Review, Volume 7, pp. 50-55.
9. Balkundi, P. and Kilduff, M., (2006). The ties that lead: A social network approach to leadership, The Leadership Quarterly, Volume17, pp. 419–439.
10. Becker, F. (2007). Organizational Ecology and Knowledge Networks, California Management Review, Volume 49, Number 2, pp. 42-61, Winter.
11. Bender-deMoll, S. and McFarland, D. A. (2006). The Art and Science of Dynamic Network Visualization, Journal of Social Structure, Volume 7, Number 2.
12. Bender-deMoll, S. (2008). Potential Human Rights Uses of Network Analysis and Mapping, A report to the Science and Human Rights Program of the American Association for the Advancement of Science, April 28, retrieved on March 20th 2009 from the AAAS Science and Human website: http://www.value-networks.com/Articles/Net_Mapping_Report.pdf
13. Berkowitz, S. D. (1982). An introduction to structural analysis: The network approach to social research. Toronto: Butterworth.
14. Brem, A. and Voigt, K-I., (2007). Innovation management in emerging technology ventures: the concept of an integrated idea management. International Journal of Technology, Policy and Management, Special Issue on Technology Based Entrepreneurship and the Management of Knowledge Bases, Volume 7, Number 3, pp. 304-321.
15. Brynjolfsson, E. and Hitt, L. M., (2003). Beyond Computation: Information Technology, Organisational Transformation, and Business Performance, Edited by Scott Morton, M.S and Laubacher, R., Inventing the Organizations of the 21st Century, MIT Press.
16. Camarinha-Matos, L. M., (2006). Collaborative network industry – Trends and foundations. DET06, Setubal
17. Camarinha-Matos, L.M., and Afsarmanesh, H., (2007). A Comprehensive Modeling Framework for Collaborative Networked Organizations. Journal of Intelligent Manufacturing, Springer Netherlands. Volume 18, Number 5. pp. 529-542.
18. Carley, K. M., (2003). "Dynamic Network Analysis" in the Summary of the NRC workshop on Social Network Modeling and Analysis, Ron Breiger and Kathleen M. Carley (Eds.), National Research Council.
19. Carr, N., (2004). "Does IT Matter? Information Technology and the Corrosion of Competitive Advantage". Boston: Harvard Business School Press.
20. Chen, C., (2007). Social networks at Sempra Energy's IT division are key to building strategic capabilities, Journal of Organizational Excellence, Volume 26, Issue 2, Pages 16-24, January.
21. Chesbrough, H., and Spohrer, J., (2006). "A research manifesto for services science", Communications of the ACM, July, Volume 49, Number. 7, pp. 35-40.
22. Cross, R. L. and Parker, A. (2004). The Hidden Power of Social Networks: Understanding how Work Really Gets Done in Organizations, Harvard Business Press.
23. Curtis, B., Keller, M. I., and Over, J., (1992), "Process Modelling", Communications of ACM, Volume 35, Number 9, September.
24. Davenport, T.H. (1993). Process Innovation, Harvard Business School Press, Boston, MA.
25. Doherty, N.F, King, M., and Al-Mushayt, O., (2003). "The Impact of Inadequacies in the Treatment of Organizational Issues on Information Systems Development Projects", Information & Management, Volume 14, pp.49-62.
26. Durland, M. M., and Fredericks, K. A., (2005). An introduction to social network analysis. New Directions for Evaluation, Volume 107, pp. 5-13.
27. Fitzsimmons, J.A. and Fitzsimmons, M.J. (2004). Service Management – Operations, Strategy, and Information Technology, Fourth Edition, International Edition. McGraw-Hill.

28. Freeman, L. C., White, D. R., and Romney, A. K., (1992). Research Methods in Social Network Analysis. Transaction Publishers, New Brunswick, New Jersey.
29. Friedman, T. L., (2006). The world is flat. New York, Penguin Books.
30. Glenn, M., (2009). "Organisational agility: How business can survive and thrive in turbulent times". A report from the Economist Intelligence Unit, The Economist, March 2009. Retrieved from Website [accessed on 1st September 2009]: http://www.emc.com/collateral/leadership/organisational-agility-230309.pdf
31. Hammer, M. and Champy, J. (1993). Reengineering the Corporation: A Manifesto for Business Revolution. New York, NY: HarperCollins Publishers.
32. Hansen, M. (1999). The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits. Administrative Science Quarterly, Volume 44, pp. 82-111.
33. Hassan, N. R., (2009). 'Using Social Network Analysis to Measure IT-Enabled Business Process Performance', Information Systems Management, Volume 26, Issue 1, pp 61-76
34. Hill, T. P., (1977). On goods and services. Review Income Wealth, Volume 23, December, pp. 315-338
35. Hubbard, D. W., (2007). How to Measure Anything, John Wiley and Sons.
36. Hsu, C., (2009). Service Science and Network Science, Service Science and Network Science - Service Science, Volume 1, Number 2, pp. i-ii.
37. Huffman, J.L. (1997). "The four Re's of total improvement", Quality Progress, Volume 30, Number 1, pp. 83-88.
38. Huysman, M., and Wulf, V., (2006). IT to support knowledge sharing in communities: towards a social capital analysis, Journal of Information Technology, Volume 21, Issue 1, pp. 40-51.
39. Jobber, D., (1998). Principles and Practice of Marketing. McGraw-Hill, NY.
40. Kaushik, A., (2007). Web Analytics – Present and Future, retrieved from Website [accessed on 12th November 2010]: http://media.wiley.com/product_data/excerpt/52/04701306/0470130652.pdf
41. Kawalek, P., and Greenwood, R. W., (2000), The Organization, The Process, and The Model, Chapter 5, pp. 61-80, in Bustard, D., Kawalek, P., and Norris, M. (2000), Systems Modeling for Business Process Improvement, Artech House Publishers.
42. Keen, P.G.W and Sol, H. G. (2008), Decision Enhancement Services – Rehearsing the Future of Decisions That Matter, IOS Press.
43. Knoke, D., and Kuklinski, J. H., (1991). Network Analysis: Basis Concepts, Chapter 14. In Thompson, G., Frances, J., Levačić, R., and Mitchell, J., (1991). Markets, hierarchies and networks: the coordination of social life. Sage Publications.
44. Krebs, V., (2007). Managing the 21st Century Organization, IHRIM Journal, Volume 9, Number 4.
45. Latour, B., (1999). 'On Recalling ANT', in J. Law & J. Hassard (eds), Actor Network Theory and After, Blackwell Publishers, Oxford, pp. 15-25.
46. Law, J., (1999). After ANT: complexity, naming and topology. In J. Law and J. Hassard (eds.), Actor network theory and after, Blackwell publisher, pp. 1-14.
47. Lewis, T. G., (2009). Network Science—Theory and Application, Hoboken, NJ: John Wiley & Sons.
48. Lundqvist, M. (2007). Information Demand and Use: Improving Information Flow within Small-scale Business Contexts. PhD Thesis, Linköping Institute of Technology at Linköping University.
49. Lusch, R. F., Vargo, S. L. and Tanniru , M. (2010). Service, value networks and learning. Journal of the Academy of Marketing Science, Volume 38, pp. 19-31.
50. Mitchell, J. C., (1969). The concept and use of social networks. Manchester, UK. Manchester University Press.
51. Monteiro, E., (2000). "Actor-Network Theory and Information Infrastructure," in: From Control to Drift, C. U. Ciborra (ed.), Oxford University Press, Oxford, pp.71-86.
52. Morabito, J., Sack, I., Bhate, A., (1999). Organization Modeling, Innovative Architectures of the 21st Century, Prentice-Hall Publishers.
53. Normann, R., (1991). Service management: Strategy and leadership in service business. 2nd edition. Chichester and New York: Wiley.

54. Normann, Richard (2001). Reframing business: when the map changes the landscape. Chichester, New Sussex: Wiley
55. Orlikowski, W.J. (1992). “The Duality of Technology: Rethinking the Concept of Technology in Organizations”, Organization Science, Volume 3, Number 3, pp.398-427.
56. Otte, E. and Rousseau, R. (2002). Social network analysis: a powerful strategy, also for the information sciences, Journal of Information Science, Volume 28, Number 6, pp. 441-453.
57. Papazoglou, M.P. (2002). The World of e-Business: Web-Services, Workflows, and Business Transactions. In Lecture Notes In Computer Science, CAiSE '02/ WES '02: Revised Papers from the International Workshop on Web Services, E-Business, and the Semantic Web, Volume 2512, pp, 153-173. London, UK. Springer-Verlag.
58. Papazoglou, M., P., (2003). Web Services and Business Transactions. World Wide Web: Internet and Web Information Systems, Volume 6, pp. 49-91. Kluwer Academic Publishers.
59. Papazoglou, M., Traverso, P., Dustdar, S., Leymann, F., Kramer, B., (2006). Service Oriented Computing Research Roadmap. In: Dagstuhl Seminar Proceedings 05462 (SOC).
60. Papazoglou, M. P., (2007). Web services: Principles and technology. Prentice-Hall.
61. Papazoglou, M. P., Huevel, W.J.v.d and Leymann, F.: Business Process Management: A Survey. ACM Computing Survey Vol. V, No. N, September, Pages 1–48 (2009)
62. Parmenter, D., (2007). Key performance indicators: Developing, implementing, and using winning KPIs. Hoboken, N.J: John Wiley & Sons
63. Pedrinaci, C., Brelage, C., van Lessen, T., Domingue, J., Karastoyanova, D., and Leymann, F., (2008). Semantic Business Process Management: Scaling up the Management of Business Processes, 2nd IEEE International Conference on Semantic Computing (ICSC) 2008, IEEE Computer Society.
64. Rai, A. and Sambamurthy, V., (2006). Editorial Notes - The Growth of Interest in Service Management: Opportunities for Information Systems Scholars. Information Systems Research, Volume 14, Number 4, pp. 327-331.
65. Reijers, H., A., Song, M., and Jeong, B., (2009). Analysis of a collaborative workflow process with distributed actors, Information Systems Frontiers, Volume 11, Issue 3, pp. 307-322.
66. Rust, R.T. and Kannan, P.T., (2002). “The Era of e-Service” in E-Service: New Directions in Theory and Practice, R. Rust and P. Kannan, (eds.), Armonk, NY: M.E. Sharpe, pp. 3-24.
67. S-Cube (2008). CD-JRA-2.1.1: Survey on Business Process Management: http://www.s-cube-network.eu/results/deliverables/wp-jra-2.1/PO-JRA-2.1.1-State-of-the-art-survey-on-business-process-modelling-and-Management.pdf
68. S-Cube (2009). CD-JRA-2.1.3.: Business Transaction Language. Available on http://www.s-cube-network.eu/working-area/activities-and-workpackages/jra-2/WP-JRA-2.1/deliverables/cd-jra-2.1.3 (2009)
69. Salancik, G. R. (1995). Wanted: A good network theory of organization. Administrative Science Quarterly, Volume 40, pp. 345-349.
70. Smith, H. and Fingar, P., (2003). Business Process Management: The Third Wave, Meghan-Kffer Press, Tampa, FL
71. Scott, J. (1991). Social Network Analysis: A Handbook. London. Sage
72. Spohrer, J., Maglio, P. P., Bailey, J., and Gruhl, D., (2007). ‘‘Steps Toward a Science of Service Systems,’’ IEEE Computer, Volume 40, Number 1, pp. 71-77.
73. Spohrer, J., and Maglio, P. P., (2008). The emergence of service science: Toward systematic service innovations to accelerate co-creation of value. Production and Operations Management, Volume 17, Number 3, pp. 238-246.
74. Spohrer, J. and Maglio, P. P. (2009). Service Science: Toward a Smarter Planet. In Service Engineering, ed. Karwowski & Salvendy. Wiley. New York, NY.
75. Sykes, T., A., Venkatesh, V., and Gosain, S., (2009). "Model of Acceptance with Peer Support: A Social Network Perspective to Understand Employees' System Use," MIS Quarterly, Volume 33, Number 2, pp.371-393.
76. Tichy, N. M., Tushman, M. L., and Frombrun, C., (1979). “Social Network Analysis for Organizations,” Academy of Management Review, Volume 4, pp. 507-519.
77. Van Heck, E., and Vervest, P., (2007). Smart business networks: how the network wins, Communication ACM, Volume 50, Number 6, pp. 28-37.

78. Van Oosterhout, M., Waarts, E., van Heck, E., and van Hillegersberg, J., (2007), Business Agility: Need, Readiness and Alignment with IT Strategies, Chapter 5, Agile Information Systems: Conceptualization, Construction, and Management, Elsevier Inc
79. Vargo, S. L., Maglio, P. P. and Akaka, M. A. (2008). On value and value co-creation: A service systems and service logic perspective. European Management Journal, Volume 26, pp. 145-152.
80. Verbeek, H., Basten, T., and van der Aalst,W., (2001). Diagnosing Workflow Processes using Woflan. The Computer Journal, Volume 44, Issue 4, pp. 246–279.
81. Walsham, G. (1995). Interpretative case studies in IS research: Nature and Method. European Journal of Information Systems, Volume 4, pp. 74-81.
82. Wang, F. Y., Carley, K. M., Zeng, D., and Mao, W., (2007). “Social computing: From social informatics to social intelligence,” Intelligent Systems, IEEE, Volume 22, Number 2, pp. 79–83, March-April.
83. Wasserman, S. and Faust, K., (1994). Social network analysis: Methods and applications. Cambridge, NY: Cambridge University Press.
84. Watts, D.J. and Strogatz, S. H., (1998). Collective Dynamics of 'Small-World' Networks, Nature, 393, pp. 440-42.
85. Watts, D. J., (2004). The “New” Science of Networks, Annual Review Sociology, Volume 30, pp. 243-270
86. Weill, P., Subramani, M., and Broadbent, M., (2002). Building IT infrastructure for strategic agility. Sloan Management Review, Volume 44, Number 1, pp. 57-65.
87. Wellman, B. & Berkowitz, S. D. (1988). Social Structures: A Network Approach. Greenwich, CT: JAI Press
88. Wellman, B., Salaff, J., Dimitrova, D., Garton, L., Gulia, M., Haythronwaite, C., (1996). Computer networks as social networks: collaborative work, telework and virtual community. Annual Review of Sociology, Volume 22, pp. 213-238.
89. Weijters, A.J.M.M. and van der Aalst, W.M.P., (2002). Workflow Mining: Discovering Workflow Models from Event-Based Data. In C. Dousson, F. Höppner, and R. Quiniou, editors, Proceedings of the ECAI Workshop on Knowledge Discovery and Spatial Data, pp. 78–84.
90. Weijters, A.J.M.M. and van der Aalst, W.M.P, (2003). Rediscovering Workflow Models from Event-Based Data using Little Thumb. Integrated Computer-Aided Engineering, Volume 10, Number 2, pp.151–162.
91. zur Mühlen, M. and Rosemann, M. (2000). Workflow-based Process Monitoring and Controlling-Technical and Organizational Issues. In R. Sprague, editor, Proceedings of the 33rd Hawaii International Conference on System Science (HICSS-33), pp. 1–10. IEEE Computer Society Press, Los Alamitos, California.
92. Zairi, M., (1997). Business process management: a boundaryless approach to modern competitiveness, Business Process Management, Volume 3, Number 1, pp. 64-80.